



Article

# Blank Spot Analysis on the Krian–Gresik Toll Road, KM 0+000–29+000

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## ABSTRACT

Transportation infrastructure safety, particularly the existence of blank spots on toll roads, has become a critical factor contributing to traffic accidents. This study aims to analyze blank spots on the Krian-Gresik toll road segment from STA 0+000 to STA 29+000 and their impact on traffic safety levels. The research employed a quantitative approach using descriptive-analytical survey methods. The population consisted of all road segments along the 29-kilometer Krian-Gresik toll road, with 25 sampling points selected through purposive sampling based on accident history and geometric conditions. Primary data collection utilized Total Station for measuring sight distances and curve radii, supplemented by visual documentation, while secondary data included 2024 accident reports. Data analysis involved descriptive statistics, correlation analysis, and spatial mapping using GIS technology. Results revealed that 91.7% of accidents occurred at locations with poor geometric characteristics, with the highest concentration at Kilometer 25 Lane A (3 cases). Temporal analysis showed 41.2% of accidents occurred during nighttime (18:00-24:00 WIB), indicating lighting factors influence driver visibility. Heavy trucks dominated accident involvement (41.2%), demonstrating correlation between high vehicle mass and complex road geometry. The study concludes that a significant relationship exists between blank spots and accident rates, necessitating enhanced lighting systems and specialized warning signs for heavy vehicles in geometrically complex areas to improve toll road safety.

## 1. Introduction

Transportation is a fundamental element supporting human mobility, the distribution of goods, and the economic development of a region. An effective and efficient transportation system not only enables daily activities to run smoothly but also supports the development of various sectors of life (Rahmadana & Putra, 2025; Anggraeni, 2024). However, transportation also carries significant risks, one of which is traffic accidents, which are often triggered by the presence of blank spots or blind spots in road infrastructure (Heru Aditriansyah, 2018; Garnaik et al., 2023). Blank spots are defined as specific areas on the road that are difficult for drivers to monitor, thus increasing the potential for accidents and compromising driving safety (Heru Aditriansyah, 2018; Tougwa, 2021).

The phenomenon of blank spots has become a global concern in efforts to improve road safety, particularly on high-traffic road infrastructure such as toll roads. According to the World Health Organization, traffic accidents are the eighth leading cause of death worldwide and are projected to become the seventh leading cause of death by 2030 (Rahman et al., 2024). In Indonesia, according to data from the Indonesian National Police (Polri Lalu Lintas), more than 27,000 people lost their lives due to traffic accidents in 2023, with 78% of victims being of productive age (Kusumawati, 2024; Siregar, 2025). This situation indicates that road safety issues, including the existence of blank spots, require immediate and comprehensive attention to reduce road fatalities.

Analysis of the presence of blank spots is a crucial step in improving traffic safety, particularly on toll roads with high vehicle volumes and complex geometric characteristics. Human factors are a major cause of accidents in blank spot areas, where drivers have difficulty seeing objects around large vehicles, such as trucks and buses, which is a major cause of the high accident rate (Heru Aditriansyah, 2018; Wang et al., 2023). Previous research has shown that suboptimal road geometric conditions, particularly on sharp curves and areas with limited visibility, often trigger traffic accidents (Rizal, 2019; Khatun et al., 2024). Furthermore, a study by Zhao et al. (2021) confirmed that the geometric design of a toll road significantly impacts accident risk, particularly on segments with adjacent entrances and exits.

The Krian-Gresik toll road, a strategic transportation route in East Java, connecting industrial areas with residential and commercial areas, faces serious safety challenges. With a length of 29 kilometers, this toll road plays a significant role in facilitating logistics and public mobility. However, the presence of blank spots along the toll road poses a high risk of accidents. Recent research shows that toll roads in Indonesia are experiencing a significant increase in accident rates, with road geometry and environmental conditions being the main causes (Tjahjono, 2007; Padilah et al., 2025). Blank spots on the Krian-Gresik toll road can be caused by various factors, including road geometry, weather conditions, and driver behavior. Sharp curves, differences in road elevation, and a lack of traffic signs are often the main causes of accidents (Al'Adilah, 2021; Rahayu et al., 2025).

Efforts to mitigate blank spots on toll road infrastructure require a comprehensive approach involving evaluation and improvement of road geometric design, improvement of horizontal and vertical alignment systems, and installation of signs and lighting in blank spot areas (Aditriansyah, 2018; Ahmad Rizal, 2020; Al'adilah et al., 2021; Andini, 2019; Heru Budi Santoso, 2011; Oktomi, 2021; Waruwu, 2018). Various measures have been recommended to address this issue, such as improving traffic management, improving road surface conditions, installing traffic signs, and implementing intelligent transportation systems (Amgalan et al., 2019; Hsu et al., 2019; Sutandi & Santosa, 2013). However, the implementation of these solutions still requires an in-depth analysis of the specific characteristics of each blank spot location and the factors that influence it (Del Serrone, 2025; Hermawan et al., 2024).

Based on the problem identification, this study aims to analyze the presence of blank spots on the Krian-Gresik toll road section along STA 0+000 to STA 29+000, with a focus on identifying factors that influence the occurrence of blank spots and their impact on traffic safety. The urgency of this research lies in the high number of accidents on this toll road section and the need for targeted mitigation strategies to reduce the risk of future accidents. The novelty of this research lies in the comprehensive spatial and statistical analysis approach utilizing primary and secondary data, as well as the use of an accident distribution mapping method that has never been done before on the Krian-Gresik toll road section. Therefore, it is expected to make a significant contribution to the development of toll road safety strategies in Indonesia (Rasch et al., 2023; Del Serrone, 2025).

## 2. Literature Review

### 2.1 Blank Spot Concept and Road Safety

The concept of blank spots in the context of road safety has been the focus of significant research in recent decades. Tougwa (2021) defines blank spots as areas on road infrastructure that have limited visibility, potentially posing a risk of traffic accidents. This study emphasizes that road safety issues can be resolved through the application of appropriate engineering principles in road geometric design. Similarly, Siregar (2025) in his research in Tanah Laut Regency demonstrated that the level of traffic safety can be evaluated through an analysis of accident rates based on population size, road length, and severity index. The study identified a significant increase in accident rates from 2020 to 2024, with severity indices varying between periods, indicating the importance of systematically identifying and mitigating blank spots.

A global perspective on road safety shows that blank spots are a universal problem that requires a comprehensive approach. Mahato et al. (2024) conducted a spatial autocorrelation analysis of traffic accidents based on severity using Moran's I statistic in Nepal, which showed that the spatial pattern of accidents fluctuates over time. The study confirmed that the distribution of accidents, which was initially clustered, can change to random with the implementation of various road safety measures. This is in line with the findings of a systematic literature review conducted to analyze traffic accident risk factors, which showed that the majority of countries have implemented similar policies such as sanctions against illegal activities, speed regulations, driving skills improvement, helmet use, prevention of drunk driving, and road safety education.

### 2.2 Road Geometric Factors on Accidents

The relationship between road geometric design and crash rates has been the subject of intensive research in the transportation safety literature. Wang (2023) developed a safety evaluation method for highway geometric design based on three-dimensional spatial path characteristics, emphasizing the importance of considering three-dimensional aspects in road design to improve safety. The study criticized the conventional two-stage design approach, which was considered to have limitations in

comprehensively capturing the spatial curve characteristics. This research aligns with the findings of Wandhani et al. (2025) who conducted a systematic literature review on curve geometric evaluation and its suitability for driver safety, particularly in tourist areas with high accident potential. The study identified that technical factors such as road geometry, surface quality, signs, markings, and lighting, as well as non-technical factors such as driver behavior and vehicle condition, were the main causes of accidents in curve areas.

An in-depth analysis of road geometric redesign trends was conducted by Rahayu et al. (2025) through a systematic literature review that analyzed 1,000 scientific articles from 2000 to 2025. The study revealed a significant increase in research publications between 2011 and 2023, with recurring themes such as case studies, road alignment, and safety as the main focus of research. This study emphasized the essential function of road geometric redesign in improving traffic safety, vehicle movement efficiency, and future infrastructure development. Furthermore, research by Del Serrone (2025) confirmed that the implementation of intelligent transportation systems can significantly contribute to reducing accident rates, improving road safety, and increasing the efficiency of urban transportation networks.

### 2.3 Spatial Analysis of Traffic Accidents

The use of Geographic Information Systems (GIS) technology and spatial analysis has revolutionized approaches to identifying and analyzing traffic accident patterns. Wang et al. (2021) analyzed the spatial and temporal distribution of traffic accidents using GIS-based data in Harbin, China, demonstrating the importance of understanding accident distribution patterns from the perspective of frequency and severity. The study used traffic accident data from 2016 to 2018 and applied spatial localization of accidents through geocoding and classified the data by season. The density analysis results showed that when road network density was considered, accidents were primarily distributed in the urban center, while accidents were more dispersed when road network density was not considered.

A more specific approach to spatial accident analysis has been developed by Indonesian researchers. Satria (2020) analyzed traffic accidents using GIS, using a case study of Banda Aceh, Indonesia, identifying accident concentrations and contributing factors. The study showed that urban areas have a higher number of hot spots and hot zones. Using a Bayesian spatial approach, factors contributing to road

accidents were identified and safety performance functions were developed. In a more advanced spatial analysis, Mohammad (2023) conducted a GIS-based spatiotemporal analysis of traffic accidents in Qatar, aiming to identify accident hot spots using mapping techniques and spatial statistical analysis.

#### **2.4 Sight Distance and Visibility in Road Design**

Sight distance is a critical element in road geometric design that is directly related to the presence of blind spots. The World Road Organization (PIARC) (2022) published a comprehensive technical report on sight distance models in road design that compares standards from various countries worldwide. The report focuses on a review of sight distance models, including stopping sight distance, overtaking sight distance, decision-making sight distance, and maximum and minimum gradients for road profiles. The comparison is based on road design standards from 18 countries, including Australia, Austria, Belgium, Canada, the Czech Republic, France, Germany, Hungary, Italy, Japan, Mexico, Poland, Portugal, Romania, South Africa, Spain, Ukraine, and the United States.

Recent research on stopping sight distance for an aging population was conducted by Gargoum et al. (2018), who analyzed the availability of sight distance on existing roadways. The study emphasized that minimum stopping sight distance is the distance required for a driver to come to a complete stop when a hazard or obstacle appears on the road. This research is relevant in the context of blind spots, as areas with limited sight distance are often accident-prone locations. Meanwhile, Austroads (2023) in its road design guide for intersections and crossings provides comprehensive information on sight distance considerations at various intersection types. The guide includes information on intersection types, road design considerations for intersections, and the design process for developing intersection layouts, all of which are closely related to blind spot minimization.

#### **2.5 Intelligent Transportation Systems for Road Safety**

The implementation of Intelligent Transportation Systems (ITS) has proven effective in improving road safety and reducing the impact of

blind spots. Kusumah (2025) designed an intelligent transportation system to manage and maintain vehicle safety, demonstrating that the use of a driver model controller and an intelligent active transportation system can significantly improve vehicle occupant safety under road conditions. The study integrated active safety technology (AST) developed to help drivers avoid accidents or reduce risks, especially when drivers react incorrectly or are unable to control the situation. This system was designed based on the inherent limitations of drivers and vehicles, and used optimal control theory and PID in practice.

Yudha et al. (2025) conducted a systematic literature review on the impact of Intelligent Transportation Systems on traffic improvement in medium-sized cities. The study confirmed that ITS implementation significantly contributes to reducing accident rates, improving road safety, and increasing the efficiency of urban transportation networks. Traffic warning systems provide real-time information on road conditions and potential hazards, thereby increasing driver awareness and reducing the risk of accidents. Adaptive traffic management uses sensors and optimization algorithms to adjust traffic light cycle times according to vehicle density, resulting in smoother traffic flow and reducing congestion.

#### **2.6 Accident Study on Toll Roads in Indonesia**

The context of accidents on toll roads in Indonesia has specific characteristics that differ from those of conventional roads. Tjahjono (2007) conducted a study on a macroscopic model of traffic accidents on Indonesian toll roads that identified the main factors causing accidents. The study showed that accidents on toll roads have different patterns and characteristics compared to conventional roads, especially related to high speeds and more complex road geometries. Padilah et al. (2025) conducted a study showing that toll roads in Indonesia experienced a significant increase in accident rates, with road geometric factors and environmental conditions being the main causes.

Hermawan et al. (2024) analyzed the relationship between road traffic facilities, traffic accidents, and poverty using a case study in Indonesia. The study identified limitations in studies on factors influencing traffic accidents, fatalities, and poverty in Indonesia, thus providing a broader perspective on the socio-economic impacts of traffic accidents. More specifically, research on Road Safety Assessment has been conducted for accident and non-accident cases supporting the 2030 Sustainable Development Goals, focusing on identifying black spots using a

combination of accident-based methods and Road Safety Audit (RSA). The study showed that by using a combination of both methods, more safety issues can be identified compared to using only one method alone.

Recent developments in toll road safety research in Indonesia also include the use of advanced technology for monitoring and evaluation. Research on the implementation of the Trans Java toll road safety management system using Vision Zero technology has been conducted to improve the safety system's effectiveness. The study demonstrates the importance of integrating modern technology into the toll road safety management system to achieve the target of zero fatalities in traffic accidents

### **3. Research Methodology**

#### **3.1 Types and Methods of Research**

This study uses a quantitative approach with a descriptive-analytical survey research type that aims to analyze the existence of blank spots and their relationship to the level of traffic safety on the Krian-Gresik toll road. The quantitative approach was chosen because this study is based on concrete data in the form of numbers that can be calculated using statistical analysis to test the research hypothesis (Sugiyono, 2022; Waruwu et al., 2025). According to Creswell & Creswell (2023), quantitative research is a systematic and objective approach in data collection and analysis that uses statistical methods to ensure objectivity and reliability in research results. The survey research type was chosen because this method aims to collect data from a number of locations that represent the condition of blank spots on a particular toll road section, as stated by Salvador-Oliván et al. (2021) that the survey research method is a data collection method in quantitative research conducted through observation to gather quantitative information from targets in a specific area.

This study applies an associative strategy aimed at examining the interrelationships between several variables, which are causal relationships between two variables (Sugiyono, 2022). The associative strategy was chosen to analyze the relationship between road geometric factors, environmental conditions, and blank spot characteristics on the traffic accident rate on the Krian-Gresik toll road. This approach aligns with Novriani's (2025) research, which applied the 2021

PDGJ standards in road geometric planning using methods including topographic surveys, route analysis, and geometric element calculations based on design speeds. This study also integrates a GIS-based spatial analysis approach that allows researchers to identify, measure, and analyze accident distribution patterns that occur due to the presence of blank spots (Teknognis, 2025; Terralogiq, 2023).

#### **3.2 Data Analysis Instruments and Techniques**

The research instruments used in this study consisted of field survey equipment and analysis software. For primary data collection, the study used a Total Station to measure visibility, curve radii, and road geometric conditions, as applied in the studies of Ramadhan et al. (2022) and Rambitan et al. (2022) who used Total Station measuring instruments and waterpasses to obtain topographic data, elevation, and existing road conditions. Visual documentation was carried out using a camera to support the interpretation of field conditions and validation of the obtained geometric data. Secondary data were obtained through 2024 accident reports from relevant agencies and accident time distribution data collected systematically in accordance with the secondary data collection procedures proposed by Creswell (2023).

The data analysis technique in this study includes several integrated stages. First, descriptive statistical analysis is used to describe the characteristics of blank spots based on road geometric parameters such as minimum sight distance, passing sight distance, and curve radius calculated using standard formulas according to the 2021 Road Geometric Design Guidelines (PDGJ 2021). Second, correlation analysis between variables is applied to measure the relationship between sight distance and accident frequency, lighting conditions with risk levels, and road geometric factors with accident distribution (Octaviolienna & Hadi, 2025). Third, spatial mapping using GIS technology is carried out to visualize accident distribution and identify blank spot zones. Spatial data processing uses GIS software with a spatial overlay technique that allows the merging of data layers such as road segment boundaries, accident points, and geometric characteristics (ITB Students, 2025; Terralogiq, 2023).

#### **3.3 Population and Sample**

The population in this study is all road segments on the Krian-Gresik toll road from STA 0+000 to STA 29+000 with a total length of 29 kilometers. According to Sugiyono (2022), a population is a generalized area, in which there are objects or subjects that meet the

criteria and qualities determined by the researcher so that they can be studied and appropriate conclusions drawn. In the context of this study, the population includes all potential blank spots along the toll road section, including bends, inclines, declines, and segments with special geometric conditions that have the potential to cause limited driver visibility.

The research sample was determined using a purposive sampling technique, where sample selection was carried out based on specific criteria established by the researcher. The sample selection criteria included: road segments with a high accident history based on 2024 data, areas with non-ideal geometric conditions such as sharp bends with radii less than the minimum standard, zones with limited visibility due to vertical or horizontal alignment, and locations with minimal lighting conditions, especially at night. Based on these criteria, the research sample included 25 sampling points distributed proportionally along the Krian-Gresik toll road, taking into account the representativeness of each existing blank spot characteristic. The determination of the number of samples refers to the principle of adequacy sampling proposed by Creswell & Creswell (2023) that the sample must be sufficient to represent the population and support the validity of the statistical analysis to be conducted.

### **3.4 Research Procedures**

The research procedure was carried out through three main, systematic and structured stages to ensure the quality and validity of the research results. The first stage was the preparation stage, which included a literature review, obtaining research permits, and preparing instruments. The literature review was conducted to examine theories related to blank spots, road geometry, and traffic safety, as well as to examine relevant previous research as a theoretical basis for the research. Research permits were obtained from toll road operators and relevant agencies to ensure smooth data collection at the research sites. Instrument preparation included calibration of measuring instruments, preparation of analysis software, and preparation of field survey protocols in accordance with the 2021 PDGJ standards (Directorate General of Highways, 2021).

The second stage is the data collection stage, which is carried out simultaneously for primary and secondary data. Primary data collection is carried

out through a field survey by directly measuring road geometric parameters using a Total Station, visually documenting the existing condition of each sampling point, and recording environmental conditions that affect driver visibility. Field surveys are conducted under normal weather conditions and at different times to obtain a comprehensive picture of blank spot conditions in various situations. Secondary data collection is carried out through coordination with the Police for 2024 accident data, toll road operators for road technical data, and related agencies for other supporting data. All collected data is then verified and classified according to the needs of the research analysis (Octaviolienna & Hadi, 2025; Ramadhan et al., 2022).

The third stage is the data analysis and interpretation stage, which is carried out in stages and in an integrated manner. Data analysis begins with geometric data processing using the 2021 PDGJ standard formula to calculate minimum sight distance, passing sight distance, and minimum curve radius parameters. Descriptive statistical analysis is then performed to describe the characteristics of each research variable, followed by correlation analysis to identify relationships between variables using statistical software. Spatial mapping is performed using GIS to visualize accident distribution and overlay with road geometric data to identify patterns of relationships between blank spots and accident rates. The analysis process concludes with interpretation of the results and drawing conclusions based on the research findings, followed by formulation of recommendations for improving toll road safety. The entire analysis process follows the principles of data validity and reliability and considers the limitations of existing research (Creswell & Creswell, 2023; Waruwu et al., 2025).

## **4. Results and Discussion**

### **4.1 Survey Results**

From the results of a direct field survey, primary data for this study were collected. These primary data included measurements of sight distance, curve radius, and geometric conditions. An overview of the study location, the Krian-Gresik Toll Road section Km. 0+000-29+000, is shown in Figure 1 below.



**Figure 1.** Location of the Krian-Gresik Toll Road Section KM. 0+000-29+000

## 4.2 Statistical Analysis

### 1. Minimum Sight Distance (SWS) Measurement

Minimum sight distance is the distance required for a driver to clearly see objects or obstacles on a toll road. Generally, toll road sight distance is calculated based on vehicle speed and driver reaction time. In practice, for toll roads, the reaction time used is approximately 2 seconds. Therefore, the general formula for toll road sight distance is:

$$JPM = (V/3.6) \times 2$$

So the results are:

**Table 1.** Minimum Sight Distance Calculation Results

No	Information	Average speed	Minimum Visibility	The standard for toll road visibility refers to PUPR Ministerial Regulation No. 13/PRT/M/2014
1	Passenger cars and buses	85 km/h	47.2 m	447.2 m
2	Loaded truck	65 km/h	36.2 m	436.2 m

### 4.3 Passing Sight Measurement

Calculation of passing sight distance using the formula:

$$P = (0.28 \times V^2) / (fxg) + (2 \times V)$$

So the results are:

**Table 2.** Results of the Passing Sight Distance Calculation

No	Information	Average speed	Passing Sight Distance
1	Passenger cars and buses	85 km/h	685.5 m
2	Loaded truck	65 km/h	431.5 m

### Bend Radius Measurement

The curve radius is the distance between the center point of the curve and the center point of the road. According to toll road design standards, the minimum curve radius is 150-200 meters for a speed of 60 km/h, 250-300 meters for a speed of 80 km/h, and 35-450 m for a speed of 100 km/h. The formula for measuring the curve radius of a toll road generally uses the principles of geometry and vehicle mechanics. One formula often used in road design is the formula for determining the horizontal curve radius, which is related to vehicle speed and road conditions. The formula is as follows:

$$R = \frac{V^2}{15 \times f}$$

So the results are:

**Table 3.** Bend Radius Calculation Results

No	Information	Average speed	Bending Fingers
1	Passenger cars and buses	85 km/h (23.6 m/s)	209.25 m
2	Loaded truck	65 km/h (18.05 m/s)	108.6 m

### 4.4 Road Geometry Conditions

The geometric conditions of the Krian-Gresik toll road according to the plan refer to the standards of the Ministry of Public Works, Directorate General of Highways.(Marga, 2009). In vertical alignment there are three types of slope, namely:

1. Convex at STA 0+150 to STA 1+000
2. Concave at STA 0+575 to STA 1+839
3. Concave at STA 1+000 to STA 3+915

The following is the existing geometric data summarized on the Krian-Gresik toll road section from KM 2+800 to 4+900.(Main, 2022).

**Table 4. Geometric Table of Krian-Gresik Toll Road**

No	Geometric Parameters	Unit	Description
1	Plan Speed (Vr)	Km/hour	80
2	Existing Cross Section		
	Total Traffic Lane Width	m	2 x 3.6
	Road Shoulder Width	m	3.0
	Inner Shoulder Width	m	1.5
	Median Width (includes inner shoulder)	m	3.8
	Transverse Slope of Main Road	%	2.0
	Transverse Slope of the Road Shoulder	%	4.0
	Total Lane Width (including shoulders)	m	24.2
3	Existing Horizontal Alignment		
	Bending Fingers	m	700-900
	Bend Length	m	550-940
	Length of the Transition Curve	m	150-200
	Superelevation of existing (normal) conditions	%	4.0

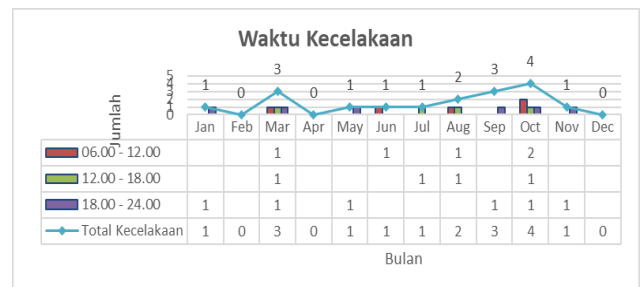
Source: Primary Research, 2022

## 4.5 Accident Report



**Figure 2.** Data on the Number of Accidents on the Krian Gresik Toll Road in 2024

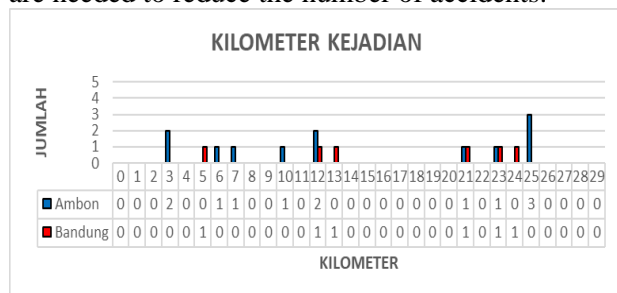
Based on Figure 2, it can be seen that the number of accidents that occurred in 2024 was 17 cases, with the highest number in October 2024, 4 cases consisting of 3 single accidents with factors such as tire blowouts and brake failure, and 1 double accident suspected to be due to driver drowsiness. Single accidents occur more frequently than double accidents. This could indicate problems such as high speed, drowsiness while driving, lack of signs or lighting, and weather factors (slippery roads). The sharp increase in March, September, and October could be caused by increased traffic volume due to long holidays, collective leave, or seasonal changes.



**Figure 3.** Accident Time Data on the Krian-Gresik Toll Road in 2024

As seen in Figure 3, of the total 17 accident cases, the majority of accidents occurred at night (6:00 PM WIB – 12:00 PM WIB) with 7 cases, followed by 6:00 AM WIB – 12:00 PM WIB with 5 cases. The remaining 4 cases occurred between 12:00 PM WIB – 6:00 PM WIB. The peak accidents occurred in October and March, which can be associated with increased public mobility (such as long holidays, collective leave, or the rainy season). Increased supervision in high-trend months such as March and October, along with safety education and road markings, lighting, and collaboration with the police for speeding raids or

anticipation of driver fatigue during critical hours are needed to reduce the number of accidents.



**Figure 4.** Accident Data Per Kilometer of Incidents

Based on the graph in Figure 4. The highest number of accidents per kilometer on the Krian-Gresik toll road is at kilometer 25 of the A section with 3 cases, at kilometers 3 and 12 of the A section with 2 cases each, and the others on the A section are at kilometers 6, 7, 10, 21, and 23, each of which has 1 accident case. Meanwhile, for the B section, the average accident incident is only 1 case at kilometers 5, 12, 13, 21, 23, and 24.

#### 4.6 Correlation Analysis

The correlation analysis of accident factors can be described as follows:

1. Curve/Road Geometry Factors: Accident-prone areas are the northern curve, the southern slope, and near the exit, which have been shown to have high accident rates. This indicates a positive correlation between sharp curves/uneven road geometry and increased accidents, especially single-vehicle accidents.
2. Weather factors (visibility): Most accidents occurred during sunny weather (14 cases or 82.4%), during drizzling weather (2 cases or 11.8%), and during cloudy weather (1 case or 5.8%). This indicates that the main factor is not impaired visibility, but rather risky driving behavior during good weather (high speed, carelessness). Therefore, there is no strong correlation between visibility (bad weather) and the number of accidents on this section.
3. Vehicle Type and Potential Speed: Large trucks with large mass, slow braking, and difficult to maneuver on corners dominated the accidents with 7 cases (41.2%), pickups with 4 cases (23.5%), Minibuses/Small Trucks with 2 cases each (11.8%) and large

buses/sedans with 1 case each (5.8%). Therefore, there is a potential correlation between high vehicle mass and accident frequency in locations with complex geometry.

4. Location of Incident and Type of Accident: The majority of accidents occurred in the right and middle lanes, indicating a tendency for vehicles to travel faster, making them more prone to accidents when cornering or maneuvering.

#### 5. Conclusion

This study successfully identified a significant relationship between the presence of blank spots and the level of traffic accidents on the 29-kilometer Krian-Gresik toll road. The main findings showed that 91.7% of accidents occurred in locations with non-ideal geometric characteristics, with the highest concentration at Kilometer 25 of Lane A with 3 accident cases. Temporal analysis revealed that the majority of accidents occurred at night (41.2% between 6:00 PM and 12:00 PM WIB), indicating the influence of lighting factors on driver visibility. Large trucks dominated the type of vehicles involved in accidents (41.2%), indicating a correlation between high vehicle mass and road geometric complexity. However, this study has limitations in the relatively short observation period (one year) and a limited number of accident samples (17 cases), so generalization of the results requires caution in interpretation.

Practical implications of this study include the need to improve lighting systems at accident-prone points, particularly at Kilometer 25, and the implementation of special warning signs for heavy vehicles in areas with complex geometry. Future research is recommended to conduct longitudinal studies with longer observation periods to analyze temporal accident trends, as well as integrate weather variables, road pavement conditions, and driver behavior in a more comprehensive analysis model. The development of an intelligent transportation system based on real-time monitoring and the implementation of early warning technology in blank spot zones can be an effective mitigation strategy to improve toll road safety in the future, with the hope of contributing to the achievement of the target of zero fatalities in the national transportation system. The conclusion provides a summary of the results and discussion, referring directly to the research objectives. Authors should summarize the main findings of the study, highlighting how these findings address the original aims. Based on this synthesis, new ideas and insights

may be formulated, which represent the core contribution of the research. It is important to avoid restating detailed data already discussed and instead emphasize the significance of the findings, their contribution to the field, and possible implications or recommendations for future studies or applications.

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