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Safety Management of Trans Java Toll Road Using Vision Zero Approach

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ABSTRACT

The Ngawi-Kertosono Toll Road, part of Indonesia's Trans-Java network, is critical for regional mobility but suffers from high accident rates due to factors like speeding and human error. This study analyzes accident data from 2020-2023, identifying key black spots with significant Equivalent Accident Numbers (EANs) that exceed safety thresholds. Recommendations include infrastructure improvements, enhanced driver education, and the adoption of advanced technologies, aligned with the Vision Zero strategy aimed at eliminating traffic fatalities. The findings emphasize a comprehensive approach involving stakeholder coordination to effectively address safety challenges and reduce accidents on this vital roadway.

Keywords: *Ngawi-Kertosono Toll Road, traffic safety, accident analysis, Vision Zero, infrastructure improvement, driver education.*

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INTRODUCTION

The Ngawi-Kertosono Toll Road serves as a vital section of Indonesia's Trans-Java Toll Road network, significantly facilitating mobility and economic activities in the region. Spanning approximately 87 kilometers, it connects strategic areas across Java and serves as a primary corridor for private vehicles and freight transport. However, the toll road also faces significant safety challenges, including a high incidence of traffic accidents.

Research indicates that excessive speeding, suboptimal road conditions, and human errors are primary contributors to these accidents, often resulting in severe injuries or fatalities (Alzayani & Alsabbagh, 2022). A lack of public awareness regarding safe driving practices further exacerbates the issue, while insufficient infrastructure in high-risk areas compounds safety concerns (Gijre & Ram, 2023). Vulnerable road users, such as pedestrians and motorcyclists, also face heightened risks and should be prioritized in safety measures.

Recent studies have highlighted the utility of surrogate safety indicators for analyzing potential risks in specific areas (Badrloo et al., 2022). Additionally, leveraging advanced technologies, such as unmanned aerial vehicles (UAVs), for traffic monitoring and data collection can yield more precise assessments of road conditions (Chen et al., 2015). Despite these advancements, coordination among stakeholders to address traffic safety

challenges remains insufficient, particularly in managing accident-prone areas or black spots (Namatovu et al., 2022).

Examining road user behavior offers valuable insights into accident causation and informs targeted interventions. Recommendations for infrastructure improvements and regulatory measures, proven effective in other contexts, are essential for mitigating these risks. A multidisciplinary approach, engaging various sectors, is critical for successfully implementing safety measures (Vinet & Zhedanov, 2011).

Globally, the Vision Zero strategy has emerged as an effective framework for reducing traffic-related fatalities and serious injuries. Originating in Sweden, Vision Zero emphasizes eliminating road deaths through infrastructure upgrades, speed regulation, and driver education (Webber et al., 2024). This study explores the potential application of Vision Zero principles to the Ngawi-Kertosono Toll Road by analyzing accident data and proposing actionable recommendations. Key interventions include improving geometric road designs, installing enhanced traffic signage, and deploying early detection technologies to reduce fatal accidents.

By adopting these measures, the study aims to significantly enhance road safety in this toll road segment, aligning with Vision Zero's ultimate goal of eliminating fatalities.

METHOD

This study focuses on the 87-kilometer Ngawi-Kertosono Toll Road segment, chosen due to its high traffic volume and significant accident rates in recent years. Data collection involved acquiring information from official sources, including the police and toll road managers. These data sets span 2020–2023 and encompass accident details such as frequency, types of vehicles involved, timing, and causal factors. Additional data on road infrastructure, including geometry, signage, and speed limits, were also analyzed to determine how these elements contribute to crashes.

Traffic flow data, including vehicle volumes and speeds, were examined to establish correlations between traffic density and accident rates. Analytical methods such as the **Equivalent Accident Number (EAN)** and the **Upper Control Limit (UCL)** were employed to measure accident severity and identify high-risk locations, or black spots. These metrics were calculated using established formulas that assign weights to various accident outcomes, such as fatalities and injuries.

Crash patterns were further analyzed based on type, time of occurrence, and weather conditions to identify trends and risk factors. A review of Vision Zero's implementation in developed countries like Sweden and the Netherlands provided valuable insights and served as a reference for developing safety strategies tailored to the Ngawi-Kertosono Toll Road.

To calculate accident severity, the EAN methodology assigns weights to different outcomes: fatalities (12), serious injuries (6), minor injuries (3), and vehicle damage (1). The formula is expressed as:

$$\mathbf{EAN = 12(MD) + 6(LB) + 3(LR) + 1(K)}$$

Where:

- MD = Number of fatalities
- LB = Number of serious injuries
- LR = Number of minor injuries
- K = Number of incidents with vehicle damage

Accident-prone areas were identified by determining whether the EAN value for a particular location exceeded a threshold calculated as the mean plus a multiple of the standard deviation (UCL). The UCL formula used is:

$$\mathbf{UCL = \mu + k\sigma}$$

Where:

- μ = Mean accident rate per kilometer
- σ = Standard deviation of accident rates
- k = Coefficient representing the desired level of strictness (commonly set to 2 or 3)

By employing these analytical tools, this study aimed to provide a comprehensive understanding of accident characteristics and formulate targeted interventions to enhance safety on the Ngawi-Kertosono Toll Road.

$$UCL = \lambda + \psi\sqrt{[(\lambda\, m) + ((0.829)\, m) + (1/2\, m)]}$$

RESEARCH RESULT

An analysis of the Ngawi-Kertosono Toll Road has highlighted several areas with many accidents, known as black spots. These areas, both on Lane A (Surabaya direction) and Lane B (Jakarta direction), have been identified as particularly dangerous, with accident rates far exceeding the upper control limits (UCL) set for safe road conditions. On Lane A, for example, the section at KM 630A has the highest recorded Equivalent Accident Number (EAN) of 138, much higher than the UCL of 43.17. This area is primarily affected by factors such as drowsy driving and drivers not being prepared for sudden changes in road conditions. Similarly, KM 631A, with an EAN of 78, and KM 619A, which recorded an EAN of 54, are also critical points for safety concerns, as both locations exceed their respective UCLs, 37.9 and 35.24. On Lane B, the section at KM 633B recorded the highest EAN of 135, significantly surpassing its UCL of 52.7, with drowsiness and tire blowouts being key contributing factors. Other black spots on Lane B, including KM 637B and KM 639B, also show high EANs of 90 and 87, indicating a consistent pattern of risky conditions in these areas.

In terms of accident timing, most incidents tend to happen during the early morning and late-night hours, periods commonly linked to driver fatigue. The types of accidents observed most frequently are collisions between multiple vehicles, followed by single-vehicle derailments. The root causes of these accidents largely stem from human errors, especially drowsiness, and failure to anticipate potential dangers on the road. Vehicle-related issues, such as tire blowouts, also play a significant role in these accidents.

To reduce these accident rates and improve safety on the toll road, several interventions have been recommended. First, infrastructure improvements are crucial, including the installation of clearer and more visible traffic signs, as well as road spikes or

delineators that can alert drivers when they are straying from their lanes. Enhancing the road's design and creating safe parking areas for rest stops would also help address the issue of driver fatigue. Furthermore, it is important to provide better education and awareness for drivers. Defensive driving training programs would help drivers better anticipate potential hazards and awareness campaigns should focus on the dangers of drowsy driving and the importance of regular vehicle maintenance to prevent mechanical failures. The introduction of advanced technology, such as fatigue detection systems and real-time traffic monitoring, could help identify risky situations and allow for faster responses to mitigate potential accidents. Lastly, stronger law enforcement is necessary, with increased patrols in high-risk areas, especially during the night, and stricter penalties for dangerous driving behaviors like speeding and not following traffic rules.

These measures are aligned with the Vision Zero approach, a strategy aimed at eliminating road fatalities and serious injuries. By implementing these recommended changes, it is expected that the safety conditions on the Ngawi-Kertosono Toll Road will improve, leading to a decrease in accidents and a safer driving environment overall.

DISCUSSION

The analysis of crash data from the Ngawi-Kertosono Toll Road reveals that certain areas, particularly those identified as black spots, pose significant safety risks due to high accident rates. These accident-prone locations are characterized by Equivalent Accident Numbers (EANs) that consistently exceed the Upper Control Limit (UCL), underscoring the need for urgent safety interventions. Key factors contributing to these accidents include human errors such as drowsy driving and a lack of anticipation, which are especially prominent during early morning and late-night hours when driver fatigue is at its peak. Additionally, vehicle-related issues such as tire blowouts exacerbate the problem, particularly in high-risk areas. Given these findings, it is evident that a comprehensive, multi-faceted approach is required to address these challenges and reduce accident rates on this vital stretch of the Trans-Java Toll Road.

One of the most effective ways to mitigate accidents on the Ngawi-Kertosono Toll Road is through infrastructure improvements. Clearer, more visible signage in accident-prone areas can significantly improve driver awareness, allowing them to anticipate potential hazards more effectively. The road geometry in certain sections may also require modifications to eliminate sharp turns, enhance visibility, and better accommodate the flow of traffic. Moreover, the introduction of delineators and designated parking bays can guide drivers more safely and provide them with places to stop and rest, addressing the critical issue of driver fatigue. By incorporating these infrastructure upgrades, the toll road will become safer, reducing the number of accidents and fatalities that have plagued certain high-risk sections.

Driver education also plays a crucial role in improving road safety. Awareness campaigns focused on the dangers of drowsy driving, distraction, and speeding can equip drivers with the knowledge needed to make safer choices. Defensive driving programs, which teach drivers how to anticipate potential hazards and respond to sudden changes in

road conditions, can further enhance overall road safety. Given that many accidents on the Ngawi-Kertosono Toll Road are linked to human errors, improving drivers' ability to recognize and avoid these risks is an essential component of any safety strategy.

Technology integration presents another critical avenue for improving safety. Real-time traffic monitoring systems can detect unusual driving behaviors, such as sudden braking or speeding, and provide authorities with valuable data to respond promptly to potential risks. Furthermore, the implementation of fatigue detection technologies, which monitor driver alertness and issue warnings when signs of drowsiness are detected, can help prevent accidents caused by driver fatigue. This technology is particularly relevant on long, monotonous stretches of toll roads, where fatigue is a significant contributing factor to accidents.

Stronger law enforcement is also essential for ensuring compliance with traffic regulations and reducing unsafe driving behaviors. Increased patrols, particularly during high-risk times such as late at night or in the early morning, will help deter violations and encourage drivers to adhere to speed limits and other safety measures. Stricter penalties for violations, such as speeding, driving under the influence, and other reckless behaviors, will send a clear message that unsafe driving practices will not be tolerated. Enhanced enforcement, combined with the infrastructure and education improvements outlined above, will create a more comprehensive approach to reducing accidents and improving safety.

The application of the Vision Zero strategy to the Ngawi-Kertosono Toll Road underscores the need for a holistic approach to road safety, which addresses both the physical road conditions and human behavior. By adopting a combination of infrastructure upgrades, driver education, technological innovations, and stricter enforcement, it is possible to significantly reduce accidents and fatalities. The Vision Zero framework, which has been successfully implemented in other countries, such as Sweden and the Netherlands, offers a proven model that can be adapted to the unique challenges faced by the Ngawi-Kertosono Toll Road. Through coordinated efforts involving various stakeholders, including toll road operators, law enforcement agencies, and public health organizations, these recommendations can be effectively implemented to create a safer environment for all road users.

Ultimately, the goal of this study is to reduce accident rates and improve road safety, not only on the Ngawi-Kertosono Toll Road but also across other sections of the Trans-Java Toll Road network. By embracing a comprehensive, data-driven approach, the Vision Zero strategy has the potential to serve as a model for enhancing traffic safety throughout Indonesia, setting a precedent for other countries in the region to follow in their efforts to reduce road-related fatalities and injuries.

Table 1. Identification of Accident Prone Areas of Ngawi - Kertosono Toll Road Lane A (Surabaya direction)

Lane A (Surabaya direction)	VICTIM			EAN			EAN	UCL	BKA	Description EAN and UCL	Description EAN and BKA
	MD	LB	LR	12 * MD	6*LB	3*LR					
KM 630 A	1	11	20	12	66	60	138	43.17	35.74	*Black Spot*	*Black Spot*
KM 631 A	4	1	8	48	6	24	78	37.9	35.74	*Black Spot*	*Black Spot*
KM 619 A	1	6	2	12	36	6	54	35.24	35.74	*Black Spot*	*Black Spot*

Source: Analysis Results, 2024

Table 2. Identification of Accident Prone Areas on the Ngawi - Kertosono Toll Road Lane B (Jakarta direction)

Lane B (Jakarta direction)	KORBAN			EAN			EAN	UCL	BKA	Ket EAN and UCL	Ket EAN and BKA
	MD	LB	LR	12 * MD	6*LB	3*LR					
KM 633 B	4	6	17	48	36	51	135	52.7	48.34	*Black Spot*	*Black Spot*
KM 637 B	3	6	6	36	36	18	90	48.85	48.34	*Black Spot*	*Black Spot*
KM 639 B	2	6	9	24	36	27	87	48.56	48.34	*Black Spot*	*Black Spot*

Source: Analysis Results, 2024

CONCLUSION

The analysis of crash data has revealed critical black spots along the Ngawi-Kertosono Toll Road that require immediate attention to improve safety. By employing the Vision Zero approach, this study has highlighted the need for a multifaceted strategy combining infrastructure enhancements, driver education, technology implementation, and stricter enforcement of traffic laws.

Table 3. Analysis of Accident Characteristics at KM 630 A

Accident Location (KM)	Time	Vehicles Involved	Type Accident
630 + 600 A	5:20 p.m. Monday, 24/4/2023	Collision (> 1 vehicle)	Front, Rear, Side Collision
630 + 100 A	19.45 Friday, 29/9/2023	Single	Derailed
630 + 200 A	At 16.40 Monday, 5/15/2023	Continuous (> 1 vehicle)	Front, Rear, Side Collision

Source: Analysis Result, 2024

Table 4. Analysis of Accident Characteristics at KM 630 A (Driver Factor)

Location	Drowsiness	Lack of Anticipation
KM 630 A	2	1

Source: Analysis Results, 2024

Table 5. Analysis of Accident Characteristics at KM 631 A

Accident Location (KM)	Time	Vehicles Involved	Accident Type
631 + 000 A	07.03 Thursday, 10/9/2020	Double	Front, Rear
631 + 100 A	05.07 Thursday, 3/12/2020	Doubles	Front, Back

Source: Analysis Result, 2024

Table 6. Analysis of Accident Characteristics at KM 631 A

Location	Drowsiness	Lack of Anticipation	Tire Rupture
KM 631 A	2		

Source: Analysis Results, 2024

Table 7. Analysis of Accident Characteristics at KM 619A

Accident Location (KM)	Time	Vehicle involved	Accident Type
619 + 450 A	05.59 Saturday, 11/1/2020	Single	Derailed
619 + 600 A	12.52 Friday, 5/11/2021	Double	Front, Rear Collision

Source: Analysis Result, 2024

Table 8. Analysis of Accident Characteristics at KM 619 A (Driver and Vehicle Factors)

Location	Drowsiness	Lack of Anticipation	Tire Rupture
KM 619 A	1	-	1

Source: Analysis Results, 2024

Table 9. Analysis of Accident Characteristics at KM 633 B (Driver Factor)

Location	Drowsiness	Lack of Anticipation	Tire Rupture
KM 633 B	4	1	1

Source: Analysis Results, 2024

Table 10. Analysis of Accident Characteristics at KM 637 B

Accident Location (KM)	Time	Vehicle Involved	Accident Type
637 + 050 B	13.15 Sunday, 5/9/2021	Single	Derailed
637 + 000 B	At 03.15 Saturday, 12/3/2022	Double	Front, Rear Collision
637 + 200 B	18.58 Wednesday, 6/14/2023	Double	Front, Rear Collision
637 + 900 B	23.55 Tuesday, 10/17/2023	Double	Front, Rear Collision

Source: Analysis Result, 2024

Table 11. Analysis of Accident Characteristics at KM 637 B (Driver Factor)

Location	Drowsiness	Lack of Anticipation
KM 637 B	4	-

Source: Analysis Results, 2024

Table 12. Analysis of Accident Characteristics at KM 639 B

Accident Location (KM)	Time	Vehicle Involved	Type Accident
639 + 300 B	05.04 Thursday, 31/12/2020	Double	Front, Rear Collision
639 + 100 B	22.05 Wednesday, 22/4/2020	Double	Front, Rear Collision
639 + 300 B	At 01.15 Monday, 13/4/2020	Double	Front, Rear Collision
639 + 600 B	22.35 Wednesday, 31/3/2021	Double	Front, Rear Collision
639 + 200 B	00.20 Sunday, 6/11/2022	Double	Front, Rear Collision

Source: Analysis Result, 2024

Table 13. Analysis of Accident Characteristics at KM 630 A (Driver Factor)

Location	Drowsiness	Lack of Anticipation
KM 639 B	4	1

Source: Analysis Results, 2024

The analysis highlights several key takeaways aimed at improving safety along the Ngawi-Kertosono Toll Road, focusing on infrastructure improvements, driver education, technology integration, and enhanced law enforcement. Infrastructure upgrades are vital in addressing accident-prone areas and ensuring safer travel for all road users. These upgrades include clearer and more visible signage to guide drivers, especially in high-risk areas, and improvements in road geometry to reduce hazards such as sharp curves and poor visibility. Additionally, the introduction of delineators and designated parking bays will help

guide drivers and provide safer places for rest, ultimately reducing the risk of accidents caused by driver fatigue. Driver education is another crucial component in improving road safety. Awareness campaigns can educate drivers about the dangers of drowsiness, distraction, and other risky behaviors, while defensive driving programs can equip drivers with skills to better anticipate potential hazards and react safely to unexpected situations. Furthermore, the integration of technology plays a significant role in proactively identifying risks and preventing accidents. Real-time monitoring systems, which track traffic patterns and detect unusual driving behaviors, can provide valuable data for managing traffic flow and identifying areas that require immediate attention. Fatigue detection technologies, such as systems that monitor driver alertness and issue warnings, can help prevent accidents caused by drowsy driving, a key concern on long stretches of toll roads. Lastly, law enforcement plays a pivotal role in ensuring compliance with traffic laws. Increased patrols in high-risk areas, especially during late-night and early-morning hours when accidents are more likely to occur, would help deter unsafe driving practices. Stricter penalties for traffic violations such as speeding, reckless driving, and failing to comply with safety regulations would further encourage drivers to adopt safer driving behaviors and reduce accident rates on the toll road. Together, these measures form a comprehensive approach to improving road safety and reducing the risk of accidents, making the Ngawi-Kertosono Toll Road a safer route for all travelers.

The Vision Zero strategy emphasizes eliminating fatalities and serious injuries on roads. Its application to the Ngawi-Kertosono Toll Road demonstrates that a holistic approach, addressing both human behavior and physical road conditions, is crucial for achieving safer transportation systems. Collaboration among stakeholders, including toll road operators, law enforcement, and public health agencies, is necessary to sustain these efforts.

With the implementation of the proposed measures, it is anticipated that accident rates will decline, advancing the Vision Zero objective of achieving zero fatalities and serious injuries. This comprehensive framework can serve as a model for improving traffic safety across other sections of the Trans-Java Toll Road and beyond.

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