

The Role of Driver Behavior in Rear-End Collisions: A Systematic Literature Review

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REVIEW

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ABSTRACT – Rear-end collisions represent a critical safety concern on Indonesian toll roads, accounting for approximately 35% of total accidents, as reported by the National Transportation Safety Committee (KNKT). Despite their frequency, limited research has explored the underlying factors contributing to these incidents. This study investigates the interplay between road geometry and driver behavior in exacerbating collision risks through a systematic literature review of 10 selected studies. Findings reveal that suboptimal geometric designs, particularly lane width variations, steep gradients, and sharp curves, contribute to erratic speed adjustments and 25% longer braking delays. Drivers' behavior exacerbates these risks, with only 40% maintaining safe following distances and average speeds exceeding limits by 10.1 km/h. Environmental factors like rain worsen conditions, increasing braking distances by 20% and creating dangerous 39 km/h speed differentials. The study identifies commercial drivers' safer practices (44-69 km/h) as evidence for professional training's effectiveness. Recommended solutions include standardizing lane designs, implementing dynamic speed systems, enhancing driver education, and deploying automated enforcement. These integrated strategies address both infrastructure and behavioral gaps while supporting ASEAN NCAP 2030 safety goals. The research provides policymakers with evidence-based interventions tailored to Indonesia's unique toll road challenges, emphasizing the need for geometric improvements combined with behavioral modifications to reduce rear-end collisions effectively.

KEYWORDS: Rear-end collisions, toll road safety, road geometry, driver behavior, speed management, traffic enforcement

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1. INTRODUCTION

Rear-end collisions represent a significant global road safety challenge (Aprianto & Syaban, 2023), accounting for approximately 30% of all traffic accidents in the United States and 20-25% in Abu Dhabi (Xi et al., 2019). Rear-end collisions are strongly influenced by both road geometry and driving behavior, especially in high-speed environments, with factors like driver distraction, reaction time, and road alignment playing critical roles (Bella & D'Agostini, 2010; Shangguan et al., 2020). Studies highlight that driver responses to geometric features such as lane width variations, horizontal curves, and gradient changes significantly influence speed maintenance and following distances (Garnaik et al., 2023; Gu et al., 2023; X. Wang et al., 2022). For instance, inconsistent lane widths can lead to erratic speed adjustments, while poor visibility on curves exacerbates delayed braking reactions. These issues are further intensified in countries with heterogeneous traffic conditions, where speed differentials between vehicle types often exceed safe thresholds, a situation that is also commonly observed in Indonesia (Siregar et al., 2023).

In Indonesia, toll roads face acute rear-end collision risks due to unique behavioral and geometric factors. Official data from the National Transportation Safety Committee (Detik.news, 2024) reveals that 35% of toll road accidents involve rear-end impacts, with driver behavior contributing to 60% of these incidents. Aggressive speeding, tailgating, and poor adaptation to geometric changes are major

contributors to unsafe driving and crash risk, especially on roads with complex or changing geometry (Farahmand & Boroujerdian, 2018; Petraki et al., 2020). The Jakarta-Cikampek Toll Road, for example, recorded a 47 km/h speed differential between cars and trucks, creating high-risk scenarios. Such conditions strain driver decision-making, especially during peak hours or adverse weather.

Driving behaviour on Indonesian toll roads is influenced by the level of compliance with safety regulations. Field data shows that only a small proportion of drivers consistently maintain a safe distance, while the majority have not adjusted their speed when passing through construction zones or encountering rainy conditions. This phenomenon aligns with the global perspective that geometric road design is insufficiently effective in reducing accident risks without changes in road user behaviour (Zeng et al., 2022). Interestingly, commercial vehicle drivers tend to choose lower speeds, for example, trucks operating within the 44-69 km/h range, indicating that professional training plays a crucial role in supporting safety.

This study employs a systematic literature review to analyze how road geometry interacts with driving behavior to exacerbate rear-end collisions on Indonesian toll roads. By synthesizing global evidence with local crash data, the research aims to propose behavior-focused interventions such as dynamic speed limits, enhanced signage for geometric hazards, and driver education programs tailored to Indonesia's high-risk corridors. The findings will address critical gaps in aligning infrastructure design with actual driver behavior, supporting Indonesia's road safety goals under the ASEAN NCAP 2030 framework.

2. METHODOLOGY

The research adopted a systematic literature review approach to synthesize existing studies relevant to rear-end collisions and toll road geometry. Scholarly articles were retrieved from three major academic databases on Google Scholar, Web of Science, and Scopus by using a combination of targeted keywords, including *"rear-end collisions toll road geometry," "driver behavior toll road safety,"* and *"road design standards rear-end crashes"*. The article filtering process is presented in the PRISMA figure.

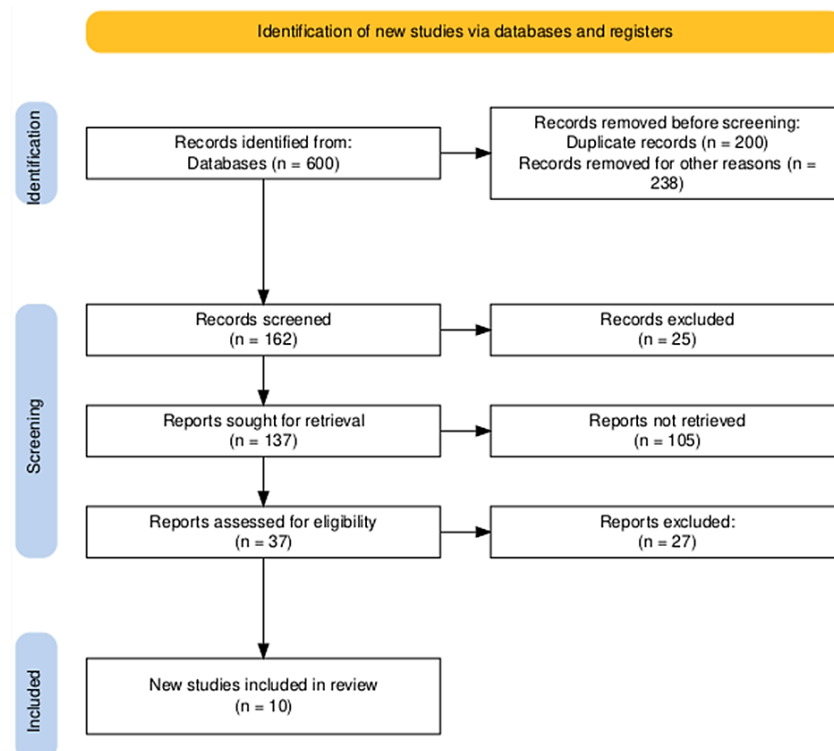


FIGURE 1: PRISMA flow diagram

The initial search yielded 600 publications. A multi-stage screening process was then implemented. First, titles and abstracts were screened to ensure relevance to the study's scope, narrowing the pool to 67 articles published within the last five years. Second, a full-text eligibility assessment was performed, applying inclusion criteria such as relevance to toll road safety, empirical or analytical focus, and alignment with the research objectives. During this process, 27 articles were excluded due to duplication, incomplete content, or lack of peer-reviewed publication status. Ultimately, 10 articles were deemed fully relevant and included in the final review (see Table S1).

3. RESULTS AND DISCUSSION

Based on a systematic literature review of 10 selected journals, this study provides critical insights into the relationship between road geometry, driver behavior, and rear-end collision risks on Indonesian toll roads. The findings are categorized into four key themes: (1) geometric design influences, (2) driver behavior patterns, (3) environmental and traffic conditions, and (4) mitigation strategies.

3.1 Impact of Road Geometry on Driver Behavior

The reviewed studies consistently indicate that suboptimal road geometric design has a substantial impact on driving behavior and collision risks. Sharafeldin et al. (2022) found that sudden lane width reductions (e.g., from 3.6m to 3.0m) increase rear-end collision risks by 18% due to erratic speed adjustments. This aligns with Didin et al. (2024) observations on Indonesian toll roads, where steep gradients caused 25% longer braking delays, particularly during rainy conditions. Han et al. (2021) further highlighted that sharp curves with small radii reduce visibility, resulting in 30% more sudden braking incidents. These geometric challenges create dangerous speed differentials between vehicles, a key factor in rear-end collisions according to Garnaik et al. (2023). Collectively, these findings highlight the necessity of adopting standardized lane width designs, optimizing gradient management, and improving curve visibility to enhance safety and reduce collision risks.

3.2 Driver Behavior and Compliance Issues

Driver behavior has been widely recognized as a critical determinant of rear-end collisions. Didin et al. (2024) identified significant compliance deficiencies, reporting that only 40% of drivers maintained safe following distances, while 70% failed to reduce speed appropriately in construction zones. Qaid et al. (2022) found that the average speed on Indonesian highways reached 90.1 km/h, despite an 80 km/h limit, reflecting widespread speeding behavior. In contrast, Han et al. (2021) documented safer practices among commercial drivers (44-69 km/h), attributing this to professional training. However, Wang and Luo (2021) warned that speed differentials exceeding 40 km/h between vehicles create high-risk scenarios with 95% collision probability. These findings collectively emphasize the critical need for behavioral interventions, including enhanced enforcement and targeted driver education programs.

3.3 Environmental and Traffic Dynamics

Environmental conditions and traffic composition significantly amplify collision risks, as demonstrated by several studies. Wang and Luo (2021) found rain increases braking distances by 20% on mountainous expressways, while Didin et al. (2024) recorded dangerous 39 km/h speed differentials during light rain on Indonesian toll roads. Construction zones exacerbate risks through lane shifts and reduced visibility (Sayed et al., 2022). Xing et al. (2023) identified unique hazards at toll plazas, where different toll collection methods create varying conflict risks, with electronically tolled vehicles showing higher risks due to abrupt speed changes. Ren et al. (2024) further confirmed these findings through micro-level traffic flow analysis at toll stations in downstream areas. These environmental and traffic-specific factors underscore the need for adaptive management strategies, including dynamic speed limits and improved road signage.

3.4 Mitigation Strategies and Policy Implications

The literature review highlights several evidence-based interventions for mitigating rear-end collisions. Sharafeldin et al. (2022) demonstrated that standardizing lane widths (≥ 3.5 m) and deploying advanced warning signs can reduce collision rates by 22%. Feng et al. (2023), Garnaik et al. (2023) and Li et al. (2022) support the adoption of dynamic speed management systems, which can decrease speed

differentials. In terms of behavioral improvements, Han et al. (2021) reported the effectiveness of professional driver training programs, while Alkaabi (2023) documented a 35% increase in compliance using automated speed cameras. Didin et al. (2023, 2024) underscore the importance of integrated strategies that combine infrastructure upgrades with behavioral interventions. Collectively, these measures align with ASEAN NCAP 2030 objectives and address Indonesia's unique toll road safety challenges through comprehensive, data-driven solutions.

4. CONCLUSION

This study highlights the critical factors contributing to rear-end collisions on Indonesian toll roads, revealing that suboptimal road geometry, such as inconsistent lane widths, steep gradients, and sharp curves, disrupts driver behavior by causing erratic speed adjustments and delayed braking. Compounding these risks are widespread driver compliance issues, including excessive speeding, inadequate following distances, and poor adaptation to construction zones or adverse weather conditions, which collectively elevate collision probabilities. Environmental factors like rainfall further exacerbate safety risks by increasing braking distances and creating hazardous speed differentials between vehicles. The findings underscore the need for integrated mitigation strategies, including the standardization of geometric design, deployment of dynamic speed management systems, targeted driver training, and stricter enforcement mechanisms. Implementing these measures is expected to significantly reduce rear-end collision rates, supporting both Indonesia's toll road safety improvements and broader regional targets under the ASEAN NCAP 2030 framework.

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SUPPLEMENTARY

TABLE S1: Results of literature review

No.	Authors	Title	Study Design	Summary
1	Sharafeldin et al. (2022)	Examining the Risk Factors of Rear-End Crashes at Signalized Intersections.	Retrospective observational study using binomial logistic regression modelling.	This study investigates the risk factors contributing to rear-end collisions at signalized intersections, focusing on variables such as commercial vehicle involvement, speeding, driver age, lighting conditions, weather conditions, area type, and pavement friction. The findings indicate that higher pavement friction, urban intersection settings, adverse weather conditions, and older drivers are associated with a reduced likelihood of rear-end crashes, whereas speeding significantly increases the risk.
2	Han et al. (2021)	Driver behaviour and traffic accident involvement among professional heavy semitrailer truck drivers in China.	Observational study.	This study developed a driving behavior scale for professional heavy semi-trailer truck drivers in China, identifying negligence/lapses and driving duration as critical factors contributing to traffic accidents, with the period between 1:00 and 5:00 a.m. posing the highest risk. The findings further indicate that positive driving behaviors significantly reduce the likelihood of accidents.
3	Sayed et al. (2022)	Studying driving behavior and risk perception: a road safety perspective in Egypt.	Observational study using a Driver Behavior Questionnaire (DBQ) with online questionnaires and field survey forms; pilot survey conducted; no randomization, blinding, or control groups mentioned.	This study examines driving behavior and risk perception in Egypt among private car, truck, and public transportation drivers, identifying human factors like failure to maintain a safe following distance as major causes of crashes. The study further recommends targeted traffic management strategies and safety interventions for implementation by local authorities.
4	Didin et al. (2022)	Exploring the Risk Factors for Rear-End Collisions on Indonesian Toll Roads.	Observational study; Purposive sampling; Structured interviews; Phone survey instrument; Non-controlled; Non-randomized; Non-blinded; Single-site.	This study explores the risk factors associated with rear-end collisions on Indonesian toll roads, with a particular emphasis on risky driving behaviors. The analysis identifies driver-related, roadway, environmental, and vehicular factors as primary contributors, and further highlights specific behaviors and toll road segments that present elevated collision risks.
5	Wang & Luo (2021)	Analyzing rear-end crash severity for a mountainous expressway in China via a classification and regression tree with random forest approach.	Retrospective observational study; single-site study; non-parametric Classification and Regression Tree (CART) model; random forest model; no randomization or blinding; no control group; no intervention; based on police-reported accidents from 2012 to 2017.	This study analyzed rear-end crash severity on mountainous expressways in China using a CART model and random forest approach, identifying key factors such as driver behaviors, vehicle type, roadway geometry, and environmental conditions, and suggesting countermeasures to improve safety.

TABLE S1: Continued.

No.	Authors	Title	Study Design	Summary
6	Qaid et al. (2022)	Speed choice and speeding behavior on Indonesian highways: Extending the theory of planned behavior.	Observational study; Convenience sampling; Self-administered questionnaire; Descriptive statistics; Structural equation modeling (SEM).	This study observed Indonesian drivers' speed choices and intentions to speed by applying the Theory of Planned Behavior, legal sanctions, and Homel's model. The results revealed an average driving speed of 90.1 km/h, with occupation emerging as a significant demographic factor. Furthermore, cognitive and affective attitudes, along with non-legal sanctions, were found to significantly influence speeding intentions.
7	Didin et al. (2024)	Analysis of Influencing Factor for Rear-end Crash on Toll Road: An Examination using Self-reported Questionnaires.	Observational study using self-reported questionnaires with a purposive sampling method.	This study examines the factors contributing to rear-end crashes on Indonesian toll roads, identifying driver, environment, and vehicle factors as key contributors, and highlights unique local behaviors such as "Lane Hogger" and trucks driving under the speed limit as significant risks, with implications for developing mitigation strategies to enhance road safety.
8	Alkaabi (2023)	Identification of hotspot areas for traffic accidents and analyzing drivers' behaviors and road accidents.	Observational study; Spatial analysis; Comparative analysis; Questionnaire survey.	This study investigates the causes of road accidents in Abu Dhabi by combining Geographic Information System (GIS) analysis to identify crash hotspots with a survey examining driver behavior. The findings indicate that careless driving is the primary cause, while age and driving experience significantly influence accident risk. The study proposes targeted preventive measures to enhance traffic safety.
9	Xing et al. (2023)	Safety Evaluation of Toll Plaza Diverging Area Considering Different Vehicles' Toll Collection Types.	Observational study, single-site, using real-world vehicle trajectory data.	This study identifies contributing factors to conflict risks in toll plaza diverging areas by analyzing vehicle-following patterns associated with electronic and manual toll collection systems. The results indicate that same-type following patterns are associated with higher severe conflict risks, with variables such as average acceleration and lane-marking indicators identified as significant for enhancing safety.
10	Ren et al. (2024a)	Traffic flow characteristics and traffic conflict analysis in the downstream area of expressway toll station based on vehicle trajectory data.	Observational study.	This study analyzes traffic flow characteristics and safety features in the downstream area of expressway toll stations using micro-level vehicle trajectory data. Findings reveal that vehicles using electronic toll collection (ETC) exhibit higher accident risks due to greater initial speeds, offering valuable insights for improving traffic management and safety at similar road nodes.