GROSTLOG 2025
Global Research on Sustainable Transport & Logistics

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

Safety Issues Related to Bald Tires in Heavy Vehicles: A Case Study of the Kluang–Mersing Highway (FT50)

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Abstract: Road safety in Malaysia continues to face challenges, particularly on federal highways such as the Kluang–Mersing Highway (FT50), which is heavily used by lorries, trailers and buses transporting goods and passengers between inland towns and the coastal region. A recurring safety concern is the use of bald or excessively worn tires, which reduce traction, braking efficiency, and vehicle stability, and significantly increase the likelihood of blowouts and severe crashes. Tires are the only point of contact between a vehicle and the road surface, and when their tread depth falls below the legal limit, particularly for heavy vehicles carrying large loads and operating with higher momentum. This study investigates the impact of bald tire usage among heavy vehicles on FT50 through a mixed-methods approach that combines roadside observations, structured surveys with 30 drivers. Findings indicate that nearly one-third of observed vehicles operated with unsafe tires, largely due to high replacement costs, operational demands, and weak enforcement mechanisms. The study concludes that bald tire usage represents a systemic safety issue shaped by economic pressures, regulatory gaps, and cultural attitudes toward compliance. It recommends continuous inspections, financial support mechanisms for operators, targeted awareness campaigns, and the integration of intelligent transport technologies to reduce risks and strengthen Malaysia's road safety culture.
Keywords: *Bald tires, heavy vehicles, road safety, enforcement, Malaysia, Kluang–Mersing Highway*

1. Introduction

The Kluang–Mersing Highway (Federal Route FT50) is a critical federal road in Johor, linking the inland commercial hub of Kluang with the eastern coastal town of Mersing. Functioning as both an economic artery and a community lifeline, the highway carries palm oil, timber, manufactured goods, passenger buses, private vehicles, and motorcycles. Its heavy usage has, however, made it one of the more accident-prone roads in the state. Among the various causes of crashes, one persistent and dangerous factor is the widespread use of bald or excessively worn tires on heavy vehicles. When tire tread falls below the legal minimum depth, the ability to disperse water diminishes, raising the likelihood of hydroplaning, extending braking distances, and increasing the risk of blowouts. Given the size, weight, and momentum of heavy vehicles, the consequences of such failures are especially catastrophic on a narrow, winding, and heavily trafficked road such as FT50 (Hamidun et al., 2019; Azami et al., 2024).

Despite existing legal requirements under the Road Transport Act 1987 and mandatory inspections by PUSPAKOM, bald tires remain a recurring issue across Malaysia, including along FT50 (Road Transport Act 1987; PUSPAKOM, 2023). Many operators particularly small fleet owners delay tire replacement to reduce costs, often relying on rethreaded tires of questionable quality (MIROS, 2022). Seasonal enforcement campaigns, such as *Ops Khas* carried out by JPJ and PDRM, have produced temporary improvements in compliance but have failed to create lasting behavioural change (Ministry of Transport Malaysia, 2019). Consequently, blowouts at highway speeds continue to occur, resulting in fatal multi-vehicle

ISSN: 2622-5778 (online)
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crashes, loss of property, disruptions to economic activity, and erosion of public confidence in road safety enforcement (TyreSafe UK, 2022; UK Department for Transport, 2020).

This study aims to investigate the prevalence, contributing factors, and enforcement effectiveness related to the continued use of bald tires among heavy vehicles operating on the Kluang–Mersing Highway (FT50), with the goal of improving road safety and supporting more effective regulatory and policy interventions**.** To achieve this aim, the research focuses on three key questions: how common bald tire usage among heavy vehicles on FT50 is, what factors influence operators' reluctance to replace unsafe tires promptly, and how effective are current enforcement practices in mitigating these risks.

The significance of this study lies in several areas. Academically, it contributes to the limited body of localized research on mechanical risk factors in road safety in Malaysia (MIROS, 2022; Azami et al., 2024). Practically, it offers insights for policymakers, enforcement agencies, and fleet operators in formulating strategies to improve safety outcomes (Ministry of Transport Malaysia, 2019; PUSPAKOM, 2025). More broadly, it highlights the systemic challenges economic, cultural, and regulatory that must be addressed to achieve sustainable reductions in highway accidents (UNECE, 2017; United States National Highway Traffic Safety Administration, 2015).

The scope of the study is confined to heavy vehicles operating along the FT50 highway. Data are gathered through driver surveys and roadside observations, complemented by triangulation with official accident records to enhance validity (Hamidun et al., 2019). However, limitations include the relatively small sample size of 30 drivers and the reliance on self-reported data, which may introduce bias. Nonetheless, the combination of multiple data sources strengthens reliability and ensures that the findings offer meaningful contributions to understanding and mitigating bald tire risks on one of Johor's most vital transport corridors.

2. Literature review

Tire safety is widely recognised as a critical determinant of road safety, particularly in the operation of heavy vehicles. Due to their large mass, high axle loads, and longer braking distances, heavy vehicles are more susceptible to severe safety consequences when mechanical failures occur. Previous studies have demonstrated that vehicle stability and braking performance are strongly influenced by the interaction between suspension systems and tire characteristics, particularly under dynamic operating conditions. Variations in load distribution, suspension behaviour, and tire deformation can significantly affect lateral stability and vehicle control, thereby increasing the risk of loss of control during manoeuvring and braking (Moreno et al., 2017).

Tire wear represents a persistent challenge in heavy vehicle operations as vehicles are continuously exposed to high loads, long travel distances, and diverse road environments. Empirical evidence shows that tire wear rates vary considerably depending on vehicle configuration, axle type, load magnitude, and route characteristics (Lepine et al., 2022). This variability makes it difficult to determine optimal replacement intervals, often resulting in prolonged tire usage under demanding conditions. When tire wear is not adequately managed, tread degradation may reduce traction and compromise braking performance, particularly on wet road surfaces, thereby increasing safety risks (Gorzelanczyk et al., 2023; Zuska et al., 2023).

The safety implications of poor tire condition are further intensified by the risk of tire failure. Tire blowouts in heavy vehicles have been shown to significantly disrupt vehicle stability and braking behaviour, frequently leading to sudden loss of control and increasing the likelihood of serious traffic collisions (Han et al., 2024). Such failures pose substantial risks not only to heavy vehicle drivers but also to surrounding road users, reinforcing the importance of preventive tire maintenance as a key component of road safety management.

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Beyond technical considerations, driver-related factors play an important role in shaping tire safety outcomes. Knowledge and awareness of tire safety influence compliance with maintenance practices and regulatory requirements. Studies indicate that drivers with higher levels of safety awareness tend to demonstrate safer behaviour, whereas limited knowledge or misconceptions may contribute to delayed tire replacement and unsafe maintenance decisions (Rahim et al., 2022). However, tire replacement behaviour is often influenced by non-safety factors such as cost considerations, convenience, and reliance on external service providers, which may reduce the priority given to safety (Mahama-Musah et al., 2020). In the Malaysian context, research specifically examining tire safety awareness among heavy vehicle drivers remains limited, with existing studies focusing more broadly on human factors and general driving behaviour (Syarah Adibah & Mohd Najib, 2021).

Drivers' attitudes and tire maintenance practices further shape safety outcomes in heavy vehicle operations. Attitudes reflect perceptions regarding safety responsibility, cost priorities, and maintenance decision-making. Economic considerations have been shown to influence preventive replacement strategies, encouraging extended use of vehicle components beyond recommended safety limits (Afrinaldi et al., 2017). In practice, tire maintenance routines are often inconsistent, particularly when inspections rely primarily on visual assessments rather than systematic monitoring, increasing the likelihood of undetected wear (Sharma & Kalra, 2022). Organisational context also plays a significant role, as maintenance practices are influenced by employment status, fleet management systems, and organisational safety culture (Rögnvaldsson et al., 2018; Hasanat-E-Rabbi et al., 2021).

Operational constraints and enforcement factors represent additional influences on tire safety compliance. High tire replacement costs, vehicle downtime, and time pressure frequently discourage timely maintenance, particularly among owner-operators and small fleet operators (Nouri Qarahasanlou et al., 2016; Dönmez & Zemmouri, 2016). Compliance behaviour is also shaped by enforcement visibility and consistency. Research on traffic behaviour indicates that adherence to safety regulations is often situational, with drivers more likely to comply when enforcement is perceived as frequent and unavoidable (King, 2015; Elvik, 2021). In Malaysia, enforcement agencies such as the Road Transport Department (JPJ) and PUSPAKOM play a central role in ensuring vehicle roadworthiness. Despite recent enhancements to inspection standards, media reports continue to document cases of heavy vehicles operating with worn or bald tires, suggesting persistent compliance challenges (Kosmo!, 2025; The Star, 2025).

Overall, the literature indicates that safety issues related to bald tires among heavy vehicles arise from a complex interaction of technical, behavioural, operational, and enforcement-related factors. While extensive research has examined vehicle safety and maintenance at a general level, limited empirical studies have focused specifically on tire-related safety issues within localised, route-specific contexts in Malaysia. This gap is particularly evident for secondary federal highways such as the Kluang–Mersing Highway (FT50), justifying the need for the present study and providing a foundation for the research objectives and methodology that follow.

Table 1. Operational definitions of study variables related to bald tire safety

Variable	Operational definition	Source
Knowledge and awareness of tire safety	Drivers' understanding of tire safety requirements, risks associated with bald tires, and basic tire maintenance knowledge.	Rahim et al. (2022); Syarah Adibah & Mohd Najib (2021)
Attitudes and tire maintenance practices	Drivers' perceptions toward tire safety, inspection routines, and tire replacement behaviour.	Afrinaldi et al. (2017); Hasanat-E-Rabbi et al. (2021)

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Operational constraints and enforcement factors	Financial pressure, operational demands, and drivers' experiences with enforcement activities influencing tire maintenance decisions.	Dönmez & Zemmouri (2016); King (2015); Elvik (2021)
Safety issues related to bald tires	Safety risks associated with worn or bald tires, including reduced braking performance, vehicle instability, and tire failure.	Gorzelanczyk et al. (2023); Han et al. (2024)

3. Research method

3.1 Introduction

This chapter explains the overall approach adopted in the study. It details the research design, population and sampling techniques, instruments used, data collection procedures, analysis strategies, ethical considerations, and limitations. The aim is to ensure transparency, replicability, and clarity in how data on bald tire usage was gathered and interpreted.

3.2 Research Design

This study employed a mixed-methods research design to capture both breadth and depth. Quantitative data provided measurable evidence on the prevalence of bald tire usage and its association with accidents, while qualitative data gave context and explained underlying motivations and enforcement challenges.

The rationale for this design is that bald tire usage is not only a technical issue but also a social and economic one. Quantitative accident statistics alone cannot reveal why operators continue to delay tire replacement, while qualitative interviews without data might lack generalizability. By integrating both approaches, the study achieved **triangulation**, increasing validity and providing a holistic understanding.

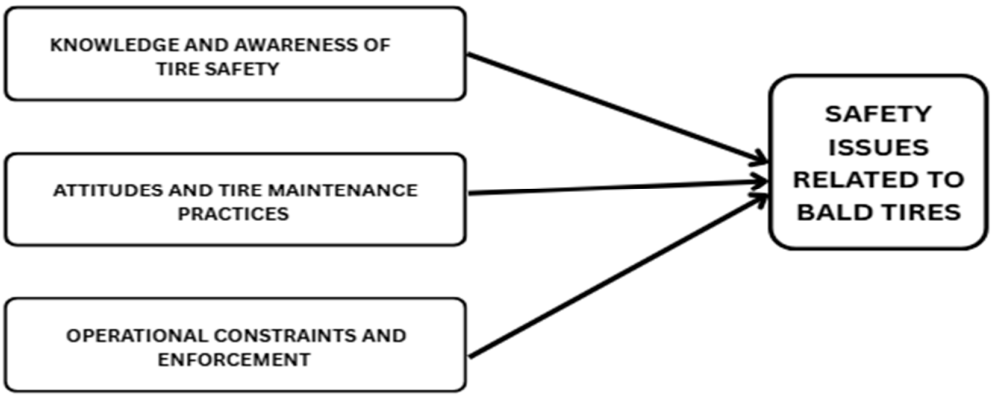

Figure 1. Conceptual framework of bald tire safety issues among heavy vehicles

3.3 Population and Sample

The population of interest consists of heavy vehicle operators (lorry and trailer) traveling along FT50 and fleet managers responsible for monitoring vehicle safety.

I. **Driver sample:** 30 drivers were selected using purposive sampling to include both compliant and non-compliant operators. This split allowed comparisons between those who maintain their tires and those who do not.

The relatively small sample size is acknowledged as a limitation, but it was mitigated by selecting participants with direct and relevant experience.

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3.4 Research Instruments

Two instruments were developed:

I. **Questionnaire** – The questionnaire was structured into four sections: demographics, maintenance practices, awareness of safety issues, and economic pressures. A combination of closed-ended questions and 5-point Likert scales were used to measure attitudes and frequency of behaviour.
   i. Example: *"How often do you inspect tire tread depth?" (1 = Never, 5 = Always).*
   ii. Example: *"To what extent do financial costs influence your tire replacement decisions?" (1 = Not at all, 5 = Very strongly).*

II. **Observation Checklist** – An inspection checklist was used during roadside checks. Variables included tire tread depth, visible cracks, inflation levels, and whether rethreaded tires were used. To maintain objectivity, data were coded numerically (e.g., 1 = legal tread depth, 0 = below legal limit).

Table 2. Summary of Questionnaire Items

Category	Example Question	Purpose
Demographics	How many years have you been driving heavy vehicles?	To profile respondent experience.
Maintenance practices	How often do you check tire tread depth?	To measure preventive behaviour.
Awareness	Do you believe bald tires increase accident risks?	To assess risk perception.
Economic pressures	How much does cost influence your tire replacement decisions?	To identify financial barriers.

3.5 Data Collection Procedures

Data collection was conducted in two stages:

I. **Survey distribution** – Questionnaires were distributed at rest stops and enforcement checkpoints along FT50. To ensure participation, drivers were briefed on the study's purpose and assured confidentiality.

II. **Roadside observations** – Conducted jointly with JPJ during inspection campaigns, observations focused on tire conditions of randomly stopped vehicles. This provided real-world verification of survey responses.

3.6 Data Analysis

Quantitative data were processed using descriptive statistics (frequencies, percentages, means) and cross-tabulations to identify relationships (between years of driving experience and maintenance practices).

Qualitative data from interviews were analysed using thematic coding. Recurring themes such as cost pressures, enforcement challenges, and cultural attitudes were identified. Combining both strands of data allowed for richer interpretation. *(Detailed statistical results and thematic coding will be inserted once full analysis is completed.)*

3.7 Reliability and Validity

Steps were taken to enhance reliability and validity:

I. **Pilot testing:** The questionnaire was piloted with 30 drivers to refine wording and structure.

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II. **Triangulation:** Findings from surveys and observations were compared to ensure consistency.
III. **Standardization:** Observation checklists followed JPJ guidelines to reduce subjectivity.
IV. **Peer debriefing:** Preliminary interpretations were shared with two transport safety researchers to check accuracy.

3.8 Ethical Considerations
All participants were briefed about the purpose of the research and gave informed consent. Participation was voluntary, and no identifying information was disclosed in the reporting. Sensitive accident records were handled in compliance with ethical standards, ensuring confidentiality.

3.9 Limitations of the Methodology
The methodology is subject to several limitations. First, the sample size is relatively small, which limits generalizability. Second, self-reported data from drivers may contain bias due to fear of legal repercussions. Third, roadside observations depend on enforcement availability, which may not capture the full scale of non-compliance. Nonetheless, triangulation of multiple sources helped reduce these weaknesses.

3.10 Summary
This chapter described the research methodology, highlighting the rationale for a mixed-methods design, sampling strategies, instruments, and ethical safeguards. While limitations exist, the approach is robust enough to provide meaningful insights into the issue of bald tire usage on FT50. The next chapter will present the results.

4. Results and discussion
4.1 Survey Findings
Respondent Profile (n=30). Most drivers were (35–44) years old (83%), followed by (45–54), with fewer younger or older participants. The sample was highly experienced: (80%)had over (11) years of driving experience. Nearly all were lorry drivers (93%), and most were company fleet drivers (73%).

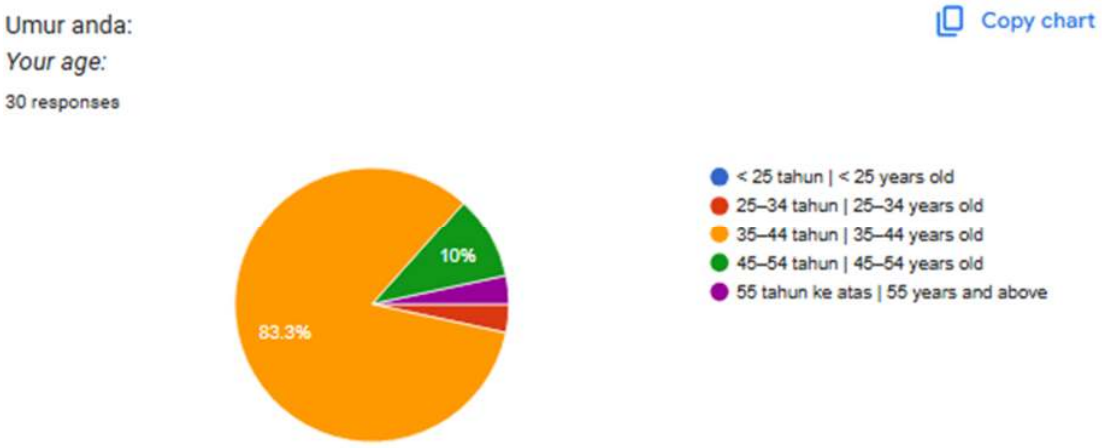

Figure 2: Demographic Age

FT50 exposure. Over half used FT50 three to five times weekly, with others reporting daily or one to two weekly trips, confirming heavy dependence on the highway.

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Figure 3: FT50 Exposure

Figure 4: Average Distance travelled daily

Maintenance practices. Tire checks ranged from daily to weekly, but not all practiced them consistently. Replacement intervals varied: one-third within (6–12 months), one-third after (1–2 years), and the rest within (6) months. About (27%) used retreads. More than half had experienced at least one blowout. Inspections were common (23/30), and two-thirds kept systematic records (20/30).

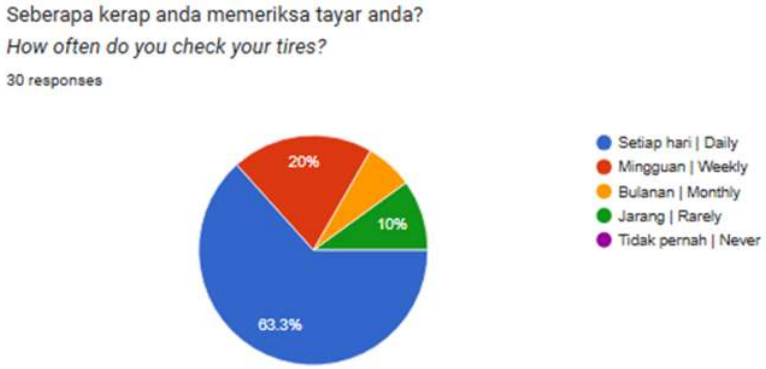

Figure 5: Tires check frequency

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Figure 6: Replacement frequency

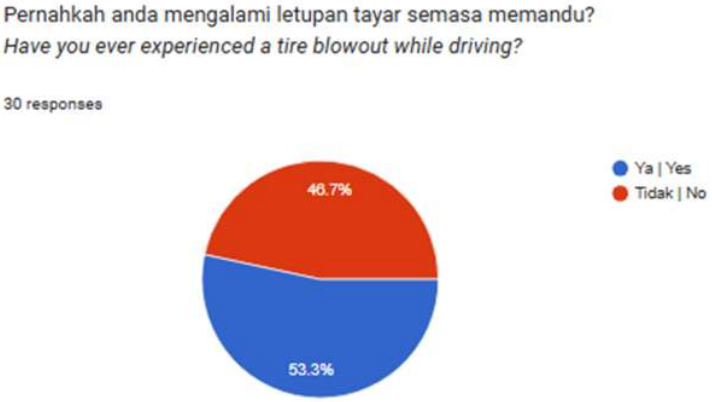

Figure 7: Blowout experience

Attitudes. Most acknowledged bald tires increase wet stopping distance and are a major crash factor. Many believed retreads can be safe if maintained, supported strict enforcement, and felt companies should bear tire costs. Few agreed with prioritising cost over safety, indicating a pro-safety mindset.

Figure 8: Bald Tires increase stopping distance on wet condition

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Figure 9: Retread tires can be safe if maintained well

Economic barriers and supports. Cost was the dominant barrier (22 mentions). Respondents identified subsidies and lower tire prices as the most helpful support, with stricter enforcement and company backing also cited. Discounts, allowances, and safety bonuses were top incentives. Open comments echoed calls for frequent inspections, better education, and financial support.

Figure 10: Incentive to encourage tire maintenance

4.2 Roadside Observation Findings

Three cases highlighted systemic issues.

I. **Small Lorry (2 axle / 6 tires).** Inner duals on the rear axle were bald and easily missed in cursory checks. Though unloaded, loading would increase risks due to heat build-up and fatigue.

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Figure 11: Small Lorry inner axel balding

II. **Semi-trailer (6 axle / 22 tires).** Multiple outer tires were bald, one showing exposed steel wires. Retreads in use were worn. The wear patterns suggested problems with inflation, rotation, and alignment

Figure 12: Semi Trailer with multiple worn out tires

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III. **Case 3 — Tipper dumper (3 axle / 10 tires).** Both steering tires were bald, posing a critical hazard since steering-axle failures compromise vehicle control.

Figure 13: Tipper Dumper with multiple balding tires

Key patterns. Inner dual defects and steering-axle baldness were the most dangerous findings. Retread presence was not inherently problematic; condition at inspection was decisive. Observations align with survey results: drivers value safety but face cost, downtime, and inspection gaps that leave unsafe tires in service.

4.3 Cross-Tab Analyses

Exploratory comparisons revealed:

I. **Retreads vs blowouts**: (59%) of non-retread users reported blowouts versus (38%) of retread users, suggesting maintenance practices influence outcomes.
II. **Records vs blowouts**: (70%) without records experienced blowouts compared to (45%) with records, showing the benefit of systematic logs.
III. **Inspection vs records**: (70%) of inspected drivers kept records versus (57%) of uninspected drivers, indicating enforcement promotes compliance.
IV. **Experience vs blowouts**: Risk persisted across all groups: (60%) of (11–20)year drivers, (50%) of (≤10 years, and 44% of >20) years had blowouts skill alone does not offset poor tire condition.
V.

4.4 Synthesis

The combined evidence demonstrates:

I. High exposure and experienced lorry drivers dominate FT50 traffic.
II. Unsafe practices persist mainly due to economic pressure and operational tempo.
III. Positive safety attitudes coexist with hazardous outcomes.
IV. Record-keeping and inspections correlate with safer outcomes.
V. Critical risks include steering-axle baldness and hidden inner dual wear.

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Figure 14: Many agreed that bald tires will cause accidents

4.5 Summary

The survey and observation findings confirm that bald tire usage is widespread across FT50's heavy-vehicle fleet. Drivers recognise the dangers and generally support safety measures, yet operational and financial constraints lead to delays in replacement. The evidence documents both the prevalence of unsafe tires and the factors shaping this condition, providing a strong factual basis for further discussion.

4.6 Discussion

The findings of this study reveal a multifaceted relationship between driver attitudes, economic constraints, enforcement practices, and systemic operational conditions that collectively contribute to the persistence of bald tire usage along the FT50 highway. While most respondents explicitly acknowledged the safety risks posed by bald tires particularly in terms of extended stopping distances, heightened likelihood of hydroplaning, and increased probability of blowouts there remains a clear disjunction between stated attitudes and observed practices. This discrepancy is evident in the continued presence of bald steering tires during roadside inspections and in the inconsistent replacement intervals reported by drivers. Such findings indicate that non-compliance is not primarily a function of ignorance or indifference to safety, but rather the result of structural constraints, most notably financial pressures and inflexible work schedules, which limit the capacity of operators to prioritise preventive maintenance.

Economic considerations emerged as the dominant factor shaping tire replacement practices. The survey results, supported by roadside observations, highlight that high replacement costs frequently discourage timely maintenance, even for vehicles operating without load. This behaviour illustrates that operators often extend the use of tires well beyond safe limits in order to delay expenditure. While rational from an economic standpoint, particularly for smaller operators and independent contractors operating under competitive arrangements, such practices externalise risks onto other road users. The reliance on rethreaded tires further reflects cost-saving strategies. Although retread tires are not inherently unsafe, the field evidence suggests that they are often used to exhaustion, thereby reducing safety margins and increasing the likelihood of catastrophic failures.

The study also underscores the limitations of current enforcement practices. Although the majority of respondents reported having undergone inspections, unsafe tires were nevertheless encountered with high frequency during field observations. Certain defects, such as inner dual wear, were particularly difficult to detect without comprehensive mechanical checks, thereby revealing inherent weaknesses in periodic inspection regimes. The predictability of inspection intervals enables operators to temporarily ensure compliance while continuing unsafe practices

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in between scheduled checks. This supports the view that while roadside inspections and checkpoint controls are essential, they are insufficient to comprehensively address tire safety risks in the long term.

At the same time, the findings point to the presence of protective factors that can mitigate risk. Cross-tabulation analyses demonstrated that drivers and companies maintaining systematic records, such as tire logbooks, reported fewer blowouts. This association suggests that administrative discipline is directly linked to safer operational outcomes. Furthermore, exposure to inspections was found to be positively correlated with better record-keeping, indicating that enforcement, when consistent, can stimulate improved safety practices. These results imply that low-cost, process-oriented measures, including mandatory record-keeping or digital monitoring of tire usage, could provide measurable safety benefits, particularly for smaller operators who lack sophisticated fleet management systems.

Importantly, the study identifies the systemic nature of the problem. The occurrence of unsafe tires was not limited to a particular vehicle type or operator group; rather, risks were found across small lorries, semi-trailers, and tippers, as well as among both company drivers and independent owner-operators. This demonstrates that tire safety issues are embedded within wider economic and operational structures rather than being confined to a marginal subgroup. The fact that highly experienced drivers were also affected by blowout incidents further reinforces that professional skill and driving experience cannot compensate for the mechanical risks associated with worn tires.

When positioned within Malaysia's broader road safety landscape, the findings highlight significant regulatory and enforcement gaps. The Road Transport Act 1987 and inspection systems such as PUSPAKOM provide a formal framework for mitigating mechanical risks, yet the persistence of bald tires indicates that regulatory structures are undermined by financial burdens and inconsistent monitoring mechanisms. The FT50 case study reflects wider national trends in which regulatory requirements are present but undermined by episodic enforcement and cultural-economic factors that weaken compliance. As such, the evidence calls for a paradigm shift from reactive, episodic inspection regimes to continuous, technology-driven monitoring systems, coupled with preventive safety cultures incentivised at both organisational and policy levels.

In conclusion, the findings suggest that while drivers are aware of and support safety principles, structural and economic realities result in widespread non-compliance with tire safety standards. Roadside observations confirmed the prevalence of hazardous practices, such as bald steering tires and hidden inner dual wear, which pose immediate threats to public safety. Nevertheless, the study demonstrates that relatively low-cost interventions, such as systematic record-keeping and targeted inspections, can reduce risks significantly. Therefore, bald tire usage should not be interpreted merely as a reflection of individual negligence, but rather as a systemic outcome requiring equally systemic solutions that encompass regulatory reform, enhanced enforcement, and organisational adaptation across the heavy vehicle sector.

5. Conclusion

This study has provided a detailed examination of bald tire usage among heavy vehicles on the FT50 highway, combining structured survey data with roadside observations to capture both perceptions and practices. The findings reveal that tire safety problems are not isolated anomalies but widespread and systemic, shaped by economic pressures, operational routines, and enforcement gaps that collectively undermine road safety.

While most drivers and operators acknowledged the dangers of using worn tires such as extended braking distances, reduced traction, and heightened risk of blowouts the realities of high operating costs and tight schedules often delayed tire replacement. Observational evidence reinforced these concerns, with bald inner duals, underinflated tires, and visible steering axle

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defects frequently recorded, especially among long-haul lorries and buses. Such conditions amplify crash risks on FT50, a highway already marked by narrow lanes, sharp curves, and heavy vehicle traffic.

The study further demonstrated that organizational practices, including systematic record-keeping, structured maintenance, and exposure to inspections, are strongly associated with safer outcomes. These protective factors highlight that improved safety requires not only stronger enforcement but also embedded compliance at the operational level.

Taken together, the findings establish bald tire usage as a structural road safety challenge rather than a matter of individual negligence. The issue reflects systemic constraints such as limited enforcement capacity, predictable inspection schedules, insufficient penalties, and economic burdens that deprioritize safety.

Ultimately, the study underscores the need for a multi-layered strategy that goes beyond awareness campaigns. Enforcement agencies must transition from episodic checks to continuous monitoring supported by technological tools, while economic measures such as subsidies or financing schemes can help ease replacement costs for smaller operators. By combining regulatory reforms, organizational improvements, and economic support, Malaysia can begin to address the entrenched risks of bald tire usage and strengthen safety outcomes along FT50 and similar highways nationwide.

6. Implications

This study provides important implications for policy, industry, and future research in relation to bald tire usage among heavy vehicles on FT50. At the policy level, the findings highlight that while regulatory frameworks such as the Road Transport Act 1987 and PUSPAKOM inspections provide a formal foundation for tire safety, their cadence and focus require strengthening. Policymakers should consider increasing the frequency of random, mobile inspections with explicit checks on high-risk areas such as inner duals and steering axles. At the same time, economic interventions including targeted subsidies or bulk purchase programs could reduce the financial burden of timely tire replacement for operators. Regulatory requirements mandating systematic tire record-keeping, whether through simple logbooks or digital applications, would further embed preventive practices into daily operations.

From an industry and operational perspective, the study underscores the significance of basic administrative discipline and preventive maintenance. Operators who maintain systematic records of tire age, mileage, and replacement intervals demonstrate substantially lower blowout risks. Emphasising company responsibility for tire costs could encourage more consistent replacement cycles, reducing the tendency to delay replacements under financial pressure. Furthermore, integrating telematics or tire pressure monitoring systems into fleet operations would provide real-time data that complements visual checks, thereby enhancing the reliability of tire safety management.

The research also opens several avenues for further investigation. Larger samples covering multiple highways would help validate whether the patterns observed on FT50 are representative of other national routes in Malaysia. More precise data could be obtained through instrumented tread depth measurements and systematic inflation logs, improving the accuracy of analysis beyond categorical roadside checks. In addition, longitudinal tracking of fleets with and without structured record-keeping practices would enable a more rigorous quantification of their protective effects.

At a broader level, addressing bald tire usage directly supports Malaysia's road safety objectives by reducing crash risks and promoting a preventive safety culture. Effective interventions must strike a balance between enforcement and support, blending punitive measures with financial and administrative tools that enable compliance. Such a balanced approach is essential to transform tire safety from being treated as a reactive legal obligation into a proactive,

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normalized practice among heavy vehicle operators. By aligning regulatory action, industry adaptation, and research advancement, the study highlights pathways toward systemic improvements in road safety across the FT50 and beyond.

7. Research limitations

Although this study provides valuable insights into the prevalence, contributing factors, and enforcement effectiveness related to bald tire usage among heavy vehicles on the FT50 highway, several limitations must be acknowledged. First, the research was confined to a single highway corridor, which may limit the generalizability of the findings to other national routes or regions with different traffic and enforcement conditions. Second, the sample size was relatively small, comprising only 30 drivers, which may not fully represent the diverse range of operators and fleet types across Malaysia. The reliance on self-reported survey data also introduces the possibility of recall bias and socially desirable responses, particularly when drivers were asked to reflect on their maintenance practices. In addition, while roadside observations provided valuable corroborative evidence, they were limited in scope and duration, capturing only a snapshot of conditions rather than long-term patterns. Finally, the study focused primarily on mechanical and enforcement dimensions of tire safety, without incorporating broader economic, cultural, or institutional factors that may also influence operator behaviour. Future research could therefore expand the geographical scope, increase sample sizes, and adopt longitudinal or quantitative methods to provide a more comprehensive and generalizable understanding of the systemic risks associated with bald tire usage in Malaysia.

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Advances in Transportation and Logistics Research
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