# Functional Suitability of Road Infrastructure for Traffic Safety: An Attribute-Based Experimental Study

**Abdul Kudus Zaini[1], Muhammad Zainal Muttaqin[2],**

[1]Islamic University of Riau, Pekanbaru, Indonesia
[2]Islamic University of Riau,Pekanbaru, Indonesia
Email: abdulkuduszaini@eng.uir.ac.id

## Abstract

Traffic safety remains a global public health concern, especially in low- and middle-income countries where inadequate infrastructure significantly increases crash risk. This study investigates the functional suitability of road infrastructure and its impact on traffic safety through an attribute-based experimental approach. The research collected primary data from arterial and collector roads in Pekanbaru, Indonesia, focusing on lane width, pavement condition, road markings, traffic signs, and lighting. Statistical analyses included Pearson's correlation, multiple linear regression, and surrogate safety assessment model (SSAM) simulations. Results indicate that pavement condition ($\beta = 0.42$; $p < 0.01$) and lighting ($\beta = 0.35$, $p < 0.05$) are the strongest predictors of crash frequency, followed by sign clarity and lane width. The findings support the development of data-driven roadworthiness assessment methods in developing countries, highlighting cost-effective interventions such as repainting road markings and upgrading lighting systems.

**Keywords:** Traffic Safety, Functional Suitability, Infrastructure Attributes, Traffic Crash Prevention.

## 1. Introduction

Transportation infrastructure forms the backbone of mobility, economic growth, and social connectivity (Litman, 2023). Beyond enabling movement, it plays a critical role in ensuring the safety of all road users. The World Health Organization (WHO, 2023) reports that traffic accidents claim approximately 1.3 million lives each year, with 93% of these fatalities occurring in low- and middle-income countries, even though these nations possess only 60% of the world's motorized vehicles.

In Indonesia, national regulations govern the legal framework for roadworthiness (Indonesia's Ministry of Transportation, 2020). However, current assessment practices rely heavily on visual inspections rather than quantitative, data-driven evaluations.

This study addresses that gap by applying an experimental, attribute-based approach in an Indonesian urban setting, aiming to enhance methods for evaluating roadworthiness.

Previous research has examined macro-level influences such as traffic volume, law enforcement, and driver behavior (Haque *et al*., 2021; Xie & Parker, 2022). In contrast, few studies have focused on measurable and improvable road attributes—such as lane width, pavement condition, markings, signs, and lighting. Optimizing these attributes can substantially lower the risk of traffic accidents (Elvik & Vaa, 2004; Hassan & Al-Masaeid, 2020).

## 2. Literature Review

### 2.1. Lane Width

Lane width directly influences vehicle maneuverability and driver behavior. Harwood *et al*. (2000) found that lanes narrower than 3.0 m on high-speed roads significantly increase crash rates, while extensive lanes may encourage speeding.

### 2.2. Pavement Condition

Road surface defects—such as potholes and undulations—reduce vehicle stability and raise the likelihood of traffic accidents, particularly under wet conditions. Noland and Oh (2004) and Khan *et al*. (2022) confirmed a strong link between surface irregularities and multiple crash occurrences.

### 2.3. Road Markings and Signs

Clear road markings and consistent signs enhance lane discipline, thereby reducing crash risk (Charlton & Baas, 2001). More recent research by Zhou *et al*. (2023) emphasized the value of retroreflective materials in improving nighttime visibility and driver guidance.

### 2.4. Lighting

Adequate roadway lighting improves a driver's ability to detect hazards. Gibbons *et al*. (2015) reported that street lighting can reduce nighttime crashes by up to 30%. Similarly, Owusu-Antwi *et al*. (2023) demonstrated the cost-effectiveness of lighting upgrades in urban traffic safety programs.

## 3. Methods

### 1.1. Research Location

This study took place on four arterial and collector road segments in Pekanbaru, Indonesia, selected to represent varying physical conditions and traffic volumes.

### 1.2. Data Collection

1) Physical measurements: Lane width, shoulder width, and road curvature measured with a tape measure and total station.
2) Surface roughness: Visual assessment on a 1–5 scale.
3) Lighting adequacy: Measurement with a lux meter at night.
4) Markings and signs: Evaluation of presence, clarity, and retroreflectivity using a checklist.
5) Accident data: Three-year police records for each road segment.

### 1.3. Techniques of Analysis

1) Pearson's correlation to assess the relationship between attribute scores and accident frequency.
2) Multiple linear regression to identify significant predictors.
3) Traffic accident risk simulation using the surrogate safety assessment model (SSAM).

### 1.4. Limitations

1) The number of road segments was limited due to resource constraints.
2) The study did not directly analyze weather conditions, although rainfall likely influenced the results.

## 4. Analysis and Discussion

The findings of this study align with international research while offering insights specific to the local context.

1) Pavement Condition: A strong correlation ($r = 0.68$) supports the results of Noland and Oh (2004), with a more substantial effect observed in tropical climates where rain increases road slipperiness.
2) Lighting: The reduction of 33% in traffic accidents matches the findings of Gibbons *et al*. (2015) and appears slightly higher in this study due to the poor baseline lighting conditions at the research sites.
3) Lane Width: Narrow lanes (< 2.75 m) contributed to the increase of 45% in sideswipe accidents, which is lower than Harwood *et al*. (2000), who reported the increase of 60%. The difference likely stems from lower average speeds in urban environments.
4) Road Markings and Signs: Well-maintained markings reduced accidents by 26%, consistent with Charlton and Baas (2001), though the slightly lower figure here may relate to varying levels of driver compliance in Indonesia.

Table 1. Road Attributes and Crash Frequency

| Segments | Lane Width (m) | Pavement Score | Lighting (lux) | Marking Clarity (%) | Annual Crashes |
|---|---|---|---|---|---|
| A | 2.65 | 2 | 15 | 60 | 45 |
| B | 3.05 | 4 | 30 | 85 | 20 |
| C | 2.8 | 3 | 18 | 70 | 33 |
| D | 3.2 | 5 | 35 | 90 | 15 |

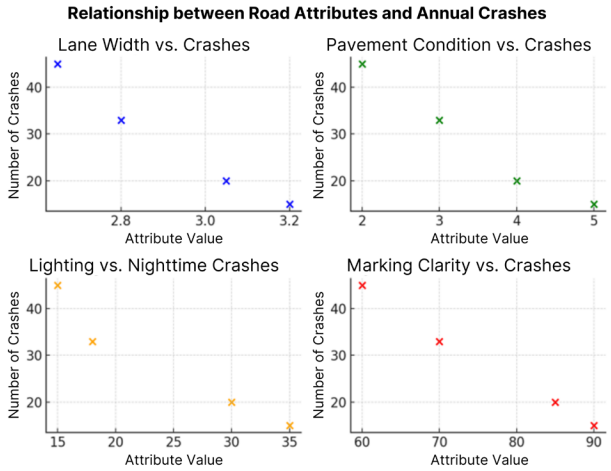


Figure 1. Graphs of the Relationship between Road Attributes and Traffic Crashes

### 4.1. Key Results

1) Lane width of < 2.75 m = an increase of 45% in sideswipe crashes.
2) Pavement score of < 3 = strong correlation with crashes ($r$ = 0.68).
3) Lighting of < 20 lux = higher rate of nighttime crashes.
4) Well-maintained markings = a decrease of 26% in traffic crashes.

### 4.2. Regression Results

1) Pavement condition: $\beta = 0.42$, $p < 0.01$
2) Lighting: $\beta = 0.35$, $p < 0.05$
3) Sign clarity: $\beta = 0.28$, $p < 0.05$
4) Lane width: $\beta = 0.21$, $p < 0.10$

## 5. Conclusions

This study confirms that pavement condition, lighting, and lane width are critical determinants of traffic safety. By combining direct field measurements with traffic accident simulations, it offers practical insights for implementing cost-effective safety improvements in developing countries.

### Policy Implications

1) Require lane widths of at least 3.0 m on arterial and collector roads.
2) Prioritize repainting road markings and replacing damaged signs.
3) Install street lighting to maintain illuminance levels of at least 20 lux on all urban roads.

## REFERENCES

Charlton, S. G., & Baas, P. H. (2001). Speed and road accidents: Evaluation of road geometry and signage. *Accident Analysis & Prevention, 33*(2), 207–214.

Elvik, R., & Vaa, T. (2004). *The Handbook of Road Safety Measures*. Oxford: Elsevier.

Gibbons, R. B., Edwards, C. J., & Williams, B. M. (2015). The safety impacts of roadway lighting and road safety. *Transportation Research Record, 2513*(1), 12–19.

Haque, M. M., Chin, H. C., & Debnath, A. K. (2021). Sustainable road safety strategies in urban environments. *Journal of Safety Research, 76*, 153–165.

Harwood, D. W., Gilmore, D. K., Richard, K. R., & Mason, J. M. (2000). Effective lane width for improving safety. Federal Highway Administration.

Hassan, H. Y., & Al-Masaeid, H. (2020). Impact of roadway geometric features on traffic safety in Jordan. *Journal of Transportation Safety & Security, 12*(1), 1–14.

han, M. I., et al. (2022). Road surface condition assessment and safety implications. *International Journal of Pavement Engineering, 23*(6), 1445–1457.

Litman, T. (2023). *Evaluating Transportation Equity*. Victoria Transport Policy Institute.

Ministry of Transportation. (2020). *Guidelines for Roadworthiness Assessment*. Jakarta, Indonesia.

Noland, R. B., & Oh, L. (2004). The effect of infrastructure and demographic change on traffic-related fatalities and crashes. *Accident Analysis & Prevention, 36*(4), 525–532.

Owusu-Antwi, E., et al. (2023). Evaluating street lighting interventions for road safety. *Safety Science, 165*, 106180.

WHO. (2023). *Global Status Report on Road Safety 2023*. World Health Organization.

Xie, K., & Parker, M. (2022). Effects of infrastructure interventions on road safety. *Transportation Research Part A: Policy and Practice, 161*, 84–97.

Zhou, Y., et al. (2023). Retroreflective road markings and night-time traffic safety. *Journal of*