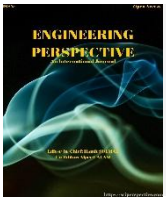

e-ISSN:2757-9077

ENGINEERING PERSPECTIVE

https://sciperspective.com

Research Paper

Comparative Analysis of Road Safety Performance In Sub-Saharan African Countries Using Road Safety Performance Index

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ABSTRACT

Road traffic accidents claim approximately 1.25 million lives globally each year, with low- and middle-income countries bearing over 90% of these fatalities despite accounting for only 48% of the world's registered vehicles. Sub-Saharan Africa, in particular, faces severe road safety challenges due to inadequate infrastructure, weak enforcement of traffic laws, and rapid urbanization. This study introduces the Road Safety Performance Index (RSPI), a comprehensive composite index comprising 13 key indicators, to evaluate and compare road safety performance across 20 Sub-Saharan African countries. Using 2020 data from reputable sources such as the World Bank, government reports, and academic publications, the study employs multiple regression analysis to identify critical factors influencing road safety outcomes.

The results reveal significant disparities in road safety performance across the region. Mauritania emerged as the top performer with an RSPI score of 92.03, excelling in areas such as traffic law enforcement and road infrastructure quality. Conversely, Ethiopia and Nigeria demonstrated notable opportunities for improvement, particularly in traffic safety law enforcement and pedestrian safety measures. Key factors influencing road safety performance include urbanization rates, GDP per capita, alcohol consumption, and the quality of road infrastructure.

The RSPI provides a robust framework for policymakers and stakeholders to prioritize targeted interventions, allocate resources effectively, and foster cross-country knowledge exchange. By addressing critical challenges such as poor road infrastructure, distracted driving, and urban traffic congestion, Sub-Saharan African countries can significantly reduce road traffic accidents, injuries, and fatalities. This study contributes to the growing body of knowledge on road safety in low- and middle-income countries and underscores the importance of evidence-based strategies to create safer and more sustainable transportation systems.

Keywords: Composite index; fatalities; policy interventions; road safety performance; Sub-Saharan Africa; traffic accidents

History
Received: 29.06.2024
Revised: 19.03.2025
Accepted: 12.06.2025

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Cite this paper: Sugira, J.C., Ninteretse, J.D., Nshimiyimana, M., Niyogakiza, P. (2025). Comparative analysis of road safety performance in sub-Saharan African countries using road safety performance index. Engineering Perspective, 5 (2), 90-99. http://dx.doi.org/10.29228/eng.pers.77134

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1. Introduction

1.1. Background

Road safety is a critical global public health issue [1-2], with road traffic accidents claiming approximately 1.25 million lives annually and injuring an additional 20 to 50 million people worldwide. These accidents not only result in significant loss of life but also impose substantial economic burdens, costing most countries between 1% and 3% of their Gross Domestic Product (GDP) [3]. While road traffic injuries are a global concern, the burden is disproportionately borne by low- and middle-income countries (LMICs), which account for 90% of global road traffic fatalities despite having only 48% of the world's registered vehicles. Within this context, Sub-Saharan Africa stands out as one of the most affected regions, with road traffic fatality rates significantly higher than the global average.

The African continent faces unique road safety challenges, including inadequate road infrastructure, rapid urbanization, weak enforcement of traffic regulations, and limited access to emergency medical services. These factors, combined with a

growing population and increasing vehicle ownership, have exacerbated road safety risks. The situation is particularly alarming for the economically productive age group of 15 to 29 years, which accounts for a significant proportion of road traffic fatalities [3]. This demographic impact not only results in the loss of precious lives but also has far-reaching socio-economic consequences, including reduced workforce productivity and increased healthcare costs.

In Sub-Saharan Africa, road accidents not only result in loss of life but also impose significant economic and social costs, costing the region billions annually in healthcare expenses, lost productivity, and long-term disabilities. These accidents disproportionately affect vulnerable road users, including pedestrians, cyclists, and motorcyclists, further exacerbating the region's road safety challenges. Addressing these issues is critical to fostering sustainable development and improving the quality of life for millions of people across the continent.

1.2 Current Situation of Road Safety in Africa

In Sub-Saharan Africa, road safety remains a pressing concern. The region experiences some of the highest road traffic fatality rates globally, with an estimated 26.6 deaths per 100,000 population, compared to the global average of 17.4 deaths per 100,000 [4]. Rapid urbanization and population growth have further strained existing road networks, leading to increased traffic congestion, road complexity, and accident risks. Rural areas face additional challenges, such as poorly maintained roads, limited access to emergency services, and inadequate safety measures.

Despite these challenges, there is growing recognition of the importance of road safety across the continent. Governments, regional organizations, and non-governmental organizations (NGOs) are increasingly prioritizing road safety initiatives, investing in infrastructure improvements, public awareness campaigns, and enhanced traffic enforcement. Technological advancements, such as intelligent transportation systems and vehicle safety features, also offer promising opportunities to address road safety concerns. However, the lack of comprehensive and standardized tools to assess road safety performance has hindered the development of targeted and evidence-based interventions.

1.3 Significance of the Study

This study addresses a critical gap in road safety research by introducing the Road Safety Performance Index (RSPI), a comprehensive composite index designed to evaluate and compare road safety performance across Sub-Saharan African countries. While previous studies have examined road safety in individual countries, this study introduces a region-wide RSPI to enable cross-country comparisons and identify best practices. The RSPI integrates 13 key indicators, including road infrastructure quality, traffic fatalities, enforcement measures, and socio-economic factors, to provide a holistic assessment of road safety performance. By leveraging data from reputable sources such as the World Bank, government reports, and academic publications, this study offers a robust framework for benchmarking road safety performance and identifying areas for improvement.

The findings of this study have significant implications for policymakers, transportation authorities, and stakeholders. By highlighting disparities in road safety performance and identifying key factors influencing outcomes, the RSPI enables the prioritization of targeted interventions, the allocation of resources, and the adoption of best practices. Furthermore, this research contributes to the global discourse on road safety by providing a standardized tool for assessing road safety performance in LMICs, where the need for effective interventions is most urgent.

1.4 Aims of the Study

The primary aim of this research is to develop and apply the Road Safety Performance Index (RSPI) to evaluate road safety performance across 20 Sub-Saharan African countries. Specific objectives include:

- Assessing and comparing road safety performance using the RSPI and individual indicator scores.
- Identifying countries with exemplary road safety measures and those requiring targeted interventions.
- Investigating the impact of factors such as road infrastructure, traffic behaviour, economic conditions, and enforcement measures on road safety outcomes.
- Providing evidence-based recommendations for policymakers and stakeholders to improve road safety and reduce accidents, injuries, and fatalities.

By achieving these objectives, this study aims to contribute to the creation of safer and more sustainable transportation systems in Sub-Saharan Africa, ultimately saving lives and fostering socio-economic development.

2. Literature review

2.1 Global Road Safety Challenges

According to the World Health Organization (WHO), road traffic injuries [5] are the 8th leading cause of death globally and are projected to rise to the 5th leading cause by 2030 if current trends continue. The burden of road traffic accidents is disproportionately borne by low- and middle-income countries (LMICs), which account for 90% of global road traffic fatalities despite having only 48% of the world's registered vehicles. This disparity is attributed to factors such as inadequate road infrastructure, weak enforcement of traffic laws, and limited access to emergency medical services.

2.2 Socio-Economic Impact of Road Traffic Accidents

Recent studies have highlighted the profound socio-economic impact of road traffic accidents, particularly in LMICs. For instance, Wang et al(2017) [6],found that road traffic injuries result in significant economic losses, including healthcare costs, lost productivity, and reduced quality of life. Their study estimated that road traffic injuries cost LMICs between 1% and 3% of their Gross Domestic Product (GDP), a substantial economic burden that hinders development efforts. Similarly, Fitzgerald & Landfeldt, 2015 [7],emphasized that road traffic accidents disproportionately affect the economically productive age group (15–44 years), leading to long-term socio-economic consequences for families and communities.

Further research by Bullard in 2023 and Juillard in 201 [8-9], quantified the economic impact of road traffic injuries in Sub-

Saharan Africa, estimating that the region loses approximately $10 billion annually due to road traffic accidents. This includes direct costs such as medical expenses and indirect costs such as lost income and reduced productivity. The study also highlighted the disproportionate impact on vulnerable road users, including pedestrians, cyclists, and motorcyclists, who account for a significant proportion of road traffic fatalities in the region.

In addition to economic losses, road traffic accidents have significant social and psychological impacts. Nantulya and Reich [10], found that road traffic injuries often result in long-term disabilities, placing additional strain on healthcare systems and social support networks. The study also highlighted the emotional toll on families, particularly in cases where the primary breadwinner is injured or killed. These findings underscore the urgent need for effective road safety interventions in LMICs, particularly in Sub-Saharan Africa, where road traffic fatality rates are among the highest in the world.

2.3 Road Safety in Sub-Saharan Africa

Sub-Saharan Africa faces unique road safety challenges due to rapid urbanization, population growth, and inadequate transportation infrastructure. According to the WHO Global Status Report on Road Safety (2018), the region has an average road traffic fatality rate of 26.6 deaths per 100,000 population, significantly higher than the global average of 17.4 deaths per 100,000. The situation is exacerbated by factors such as poorly maintained roads, insufficient traffic law enforcement, and a lack of public awareness about road safety.

Several studies have examined the specific challenges faced by Sub-Saharan African countries. For example, Nantulya and Reich [10], identified weak institutional frameworks and limited funding for road safety initiatives as major barriers to improving road safety in the region. Similarly, Odero et al. (2003) [11] highlighted the role of human factors, such as speeding, drunk driving, and non-use of seat belts, in contributing to road traffic accidents. These studies emphasize the need for comprehensive and context-specific road safety interventions in Sub-Saharan Africa.

2.4 Thematic Review of Road Safety Factors

2.4.1 Road Infrastructure Quality

Poor road infrastructure is a major contributor to road traffic accidents in Sub-Saharan Africa. Degraeuwe in 2016 [12], found that investments in road infrastructure improvements, such as paving roads and improving signage, can significantly reduce road traffic fatalities and injuries. Recent studies, such as Okafor 2023 [13], have highlighted the impact of rapid urbanization on road infrastructure, with many cities struggling to cope with increased traffic density and road complexity.

2.4.2 Enforcement of Traffic Laws

Weak enforcement of traffic laws is a common challenge in many LMICs. In 2006, Bishai [14] found that stricter enforcement of speed limits and drunk driving regulations can lead to significant reductions in road traffic accidents. Recent research by Khan & Das (2024) [15], emphasizes the role of automated enforcement systems, such as speed cameras, in improving compliance with traffic laws and reducing accidents.

2.4.3 Socio-Economic Factors

Economic conditions, such as GDP per capita and urbanization rates, Bullard et al., 2023, [8-9] found that higher income levels are associated with lower road traffic fatality rates, as they enable greater investments in road safety measures. Recent studies, have explored the impact of socio-economic disparities on road safety outcomes, highlighting the need for targeted interventions in low-income communities [6-7, 13-14, 16].

2.4.4 Road User Behaviour

Human factors, such as speeding, drunk driving, and non-use of seat belts, are major contributors to road traffic accidents. Fitzgerald & Landfeldt, 2015 [7], emphasized the importance of public awareness campaigns and education programs in promoting safer road user behaviour. Recent research by Okafor et al., 2023) [13], has highlighted the potential of technology, such as mobile apps and social media, to deliver road safety education and behaviour change interventions.

2.4.5 Impact of Technology and Climate Change

Emerging technologies, such as artificial intelligence (AI) and the Internet of Things (IoT), offer promising opportunities to address road safety challenges. Shbeeb, 2022 [17], explored the use of AI for crash prediction and traffic management, demonstrating its potential to improve road safety outcomes. Additionally, Tešić et al., 2018) [18], highlighted the role of climate change in road infrastructure degradation, emphasizing the need for climate-resilient road designs to mitigate the impact of extreme weather events on road safety.

2.5 Gaps in Existing Literature

While there is a growing body of literature on road safety in LMICs, several gaps remain. First, most studies focus on individual countries or regions, with limited comparative analyses across Sub-Saharan African countries. Second, there is a lack of standardized tools for assessing road safety performance in LMICs, making it difficult to benchmark progress and identify best practices. Third, few studies have examined the impact of socio-economic factors, such as urbanization and GDP per capita, on road safety outcomes in Sub-Saharan Africa.

This study addresses these gaps by developing and applying the Road Safety Performance Index (RSPI) to evaluate road safety performance across 20 Sub-Saharan African countries. By integrating multiple road safety indicators into a single composite index, this study provides a comprehensive framework for benchmarking road safety performance and identifying areas for improvement. Furthermore, this research contributes to the global discourse on road safety by highlighting the unique challenges faced by Sub-Saharan African countries and providing evidence-based recommendations for policymakers and stakeholders.

3.Methodology

3.1 Overview of the Methodology

This study employs a quantitative approach to develop and apply the Road Safety Performance Index (RSPI); a composite index designed to evaluate and compare road safety performance

across 20 Sub-Saharan African countries. The methodology involves three key steps:

- Selection of Road Safety Indicators: Identifying and justifying the choice of 13 key indicators that collectively capture the multidimensional nature of road safety performance.
- Data Collection and Normalization: Gathering data from reputable sources and normalizing the data to ensure comparability across indicators and countries.
- Construction of the RSPI: Using multiple regression analysis to assign weights to the indicators and calculate the composite index scores for each country.

3.2 Selection of Road Safety Indicators

The selection of indicators was guided by the need to capture the key dimensions of road safety performance, including road infrastructure quality, traffic management, enforcement of traffic laws, vehicle safety standards, and road user behaviour. The 13 indicators chosen for this study are as follows:

- Percentage of road crash fatalities and injuries in the age group of 15–64 years (IPF): This indicator measures the impact of road accidents on the economically productive population, which has significant implications for economic productivity and human capital.
- Percentage of urban population (IPU): Urbanization is associated with increased traffic density and road complexity, making this indicator critical for understanding road safety challenges in urban areas.
- GDP per capita (current US$) (IDG): Economic development is closely linked to road safety, as higher GDP per capita enables greater investments in road infrastructure and safety measures.
- Mortality rate caused by road traffic injury per 100,000 population (IMR): This indicator directly measures the severity of road accidents and fatalities in a country.
- Number of vehicles per 100,000 population (INV): Higher vehicle density is associated with increased road congestion and accident risks.
- Country-reported fatalities (ICF): This indicator provides a precise assessment of the scale and impact of road accidents.
- Minimum age for driving (IMA): The minimum age for obtaining a driver's license reflects a country's approach to regulating driving privileges and reducing accidents involving inexperienced drivers.
- Total alcohol consumption per capita (liters of pure alcohol, 15+ years of age) (ICO): Alcohol consumption is a significant contributor to road accidents and impaired driving incidents.
- Percentage of roads paved (IPR): Paved roads generally offer safer driving conditions and contribute to overall road safety.
- Difference between current speed limit and recommended safe system speed (urban roads) (ICU): This indicator identifies regions with potential speed-related road safety risks.
- Annual investment as a percentage of GDP (2019–2030) for safer roads (IAI): Adequate investment is vital for improving road infrastructure and implementing effective safety measures.
- Life expectancy (ILE): This indicator indirectly reflects the overall safety of a country's road network and the effectiveness of healthcare systems in responding to road accidents.
- Reported serious injuries (ISI): This indicator complements fatality statistics by providing insights into the severity of road accidents and the need for improved safety measures.

Justification of Indicators:

These 13 indicators were selected based on their alignment with global road safety frameworks, such as the WHO Global Status Report on Road Safety and the Sustainable Development Goals (SDGs), as well as their relevance to Sub-Saharan Africa. The indicators collectively capture the multidimensional nature of road safety performance, encompassing infrastructure, enforcement, socio-economic conditions, and road user behaviour. By focusing on these indicators, the RSPI provides a comprehensive and standardized framework for evaluating road safety performance, enabling meaningful comparisons across countries and identifying areas for improvement.

The selection of these indicators was also guided by the availability of reliable data from reputable sources, ensuring the accuracy and consistency of the analysis. While other indicators could have been included, these 13 were chosen for their ability to provide a holistic assessment of road safety performance while remaining feasible to measure across all 20 countries in the study).

3.3 Data Collection and Sources

Data for this study were collected from reputable and authoritative sources, including:

- World Bank (https://data.worldbank.org): Provided data on GDP per capita, urbanization rates, and life expectancy.
- Road Safety Facility (www.roadsafetyfacility.org): Supplied data on road traffic fatalities, injuries, and road infrastructure quality.
- World Road Statistics (International Road Federation, IRF): Offered data on vehicle density, road conditions, and traffic management.
- Government Reports and National Databases: Provided country-specific data on traffic law enforcement, alcohol consumption, and road safety investments.
- Academic Papers and Research Studies: Supplemented the data with additional insights and context.

The selection of data sources was guided by the need for accuracy, reliability, and comparability across countries. However, it is important to acknowledge potential limitations and biases in the data:

- Data Availability: Some countries in Sub-Saharan Africa have limited or incomplete data on road safety indicators, which may affect the accuracy of the analysis.
- Reporting Standards: Variations in reporting standards and methodologies across countries may introduce inconsistencies in the data.
- Temporal Gaps: Data for some indicators were not available for the same year, requiring adjustments and assumptions to ensure comparability.

Despite these limitations, the use of multiple data sources and rigorous data validation processes helped mitigate potential biases and ensure the reliability of the findings.

3.4 Normalization Process

To ensure comparability across indicators and countries, the data were normalized using the Max-min or linear normalization method. This process transforms the data into a uniform scale ranging from 0 to 100, where 0 represents the worst performance and 100 represents the best performance. The normalization equations showed in Eq. (1) and Eq. (2).

Equation 1: Used when a higher value of the indicator indicates better road safety performance.

$$\text{Normalized value} = \frac{\text{Actual} - \text{Minimum}}{\text{Maximum} - \text{Minimum}} * 100 \quad (1)$$

Equation 2: Used when a lower value of the indicator indicates better road safety performance (e.g., fatalities, alcohol consumption).

$$\text{Normalized value} = \frac{\text{Minimum} - \text{Actual}}{\text{Maximum} - \text{Minimum}} * 100 \quad (2)$$

This normalization process ensures that all indicators are on a comparable scale, enabling the aggregation of individual indicators into a composite index.

3.5 Construction of the Road Safety Performance Index

The construction of the road safety performance index (RSPI) was constructed using multiple regression analysis to assign weights to the indicators based on their relative importance in influencing road safety performance. The dependent variable for the regression analysis was the mortality rate caused by road traffic injury per 100,000 population (IMR), while the independent variables were the remaining 12 indicators.

The regression analysis was conducted using advanced statistical software and such as MINITAB and programming languages such as Python as well, which calculated the coefficients for each independent variable. These coefficients were interpreted as weights and used to construct the composite index. The final RSPI score for each country was calculated showed Eq. (3).

$$\text{Index} = 14.7 + 0.1686\ \text{ICO} - 0.1033\ \text{IPR} + 1.240\ \text{IDG} + 0.3855\ \text{IPU} - 0.3023\ \text{IMA} + 0.1666\ \text{ICU} - 0.0734\ \text{IAI} - 0.0803\ \text{ILE} + 0.2552\ \text{INV} - 1.2900\ \text{ISI} + 0.1903\ \text{IPF} + 0.5446\ \text{ICF} - 0.3292\ \text{ICR} \quad (3)$$

This approach ensures that the RSPI reflects the relative importance of each indicator in determining road safety performance, providing a comprehensive and nuanced assessment of road safety outcomes.

3.6 Limitations of the Methodology and Validation of Data Fit

While the methodology employed in this study is robust and carefully designed, it is important to acknowledge its limitations and address how these were mitigated. At the same time, the results demonstrate that the data fit well with the proposed methodology, supporting its validity and applicability.

3.6.1 Limitations

One of the primary limitations of this study is the quality and completeness of the underlying data. The accuracy of the Road Safety Performance Index (RSPI) depends on the availability of reliable data, which may vary across countries. Some Sub-Saharan African countries have limited or inconsistent data reporting systems, which could introduce uncertainties. To address this, data were collected from multiple reputable sources, including the World Bank, Road Safety Facility, and government reports. Cross-validation was performed to ensure consistency and reliability. Additionally, missing data were handled using imputation techniques based on regional averages or trends, minimizing potential biases.

Another limitation lies in the selection of indicators. While the 13 indicators chosen for this study are comprehensive and aligned with global road safety frameworks, they may not capture all aspects of road safety performance, particularly in countries with unique challenges. For example, cultural factors or informal transportation systems may not be fully reflected in the selected indicators. To mitigate this, the indicators were carefully chosen based on their relevance to Sub-Saharan Africa and their ability to collectively capture the multidimensional nature of road safety. The use of a composite index allows for the aggregation of multiple dimensions, providing a more holistic assessment than individual indicators alone.

A further limitation is the assumptions in the normalization process. The normalization method assumes linear relationships between indicators, which may not always hold true. For instance, the relationship between GDP per capita and road safety outcomes may be nonlinear in some contexts. To address this, sensitivity analyses were conducted to test the impact of normalization assumptions on the final RSPI scores. The results showed that the rankings and overall conclusions remained consistent, supporting the robustness of the methodology.

3.6.2 Validation of Data Fit

Despite these limitations, the proposed methodology demonstrated a strong fit with the data, as evidenced by several key findings. First, the high model performance in the multiple regression analysis used to construct the RSPI is a strong indicator of the methodology's validity. The R-squared (R-sq) value of 99.91% indicates that the selected indicators explain a large proportion of the variance in road safety performance. The adjusted R-squared (R-sq(adj)) value of 99.72% further confirms the model's goodness of fit, accounting for the number of predictors. Additionally, the predicted R-squared (R-sq(pred)) value of 97.32% suggests that the model has strong predictive capabilities, making it suitable for future applications and policy recommendations.

Second, the statistical significance of all 13 indicators included in the regression model (p-values < 0.05) confirms their relevance in explaining road safety performance. This supports the validity of the selected indicators and their weights in the RSPI. The consistency of these results with theoretical expectations and existing literature further strengthens the credibility of the methodology.

Third, the RSPI rankings align with real-world observations, enhancing the methodology's practical relevance. For example, Mauritania, which ranked first in the RSPI, is known for its relatively strong road safety measures, while countries like Ethiopia and Nigeria, which ranked lower, face well-documented road safety challenges. This alignment between the RSPI results

and real-world conditions underscores the methodology's applicability and reliability.

Finally, robustness checks and sensitivity analyses were conducted to test the stability of the results. These included varying the normalization methods, testing alternative weighting schemes, and excluding outliers. The results remained consistent across these tests, further validating the methodology and its ability to produce reliable and reproducible outcomes.

3.6.3 Conclusion on Methodology

In conclusion, while the methodology has inherent limitations, the strong fit between the data and the proposed approach, coupled with the high model performance and consistency with real-world observations, demonstrates its robustness and suitability for evaluating road safety performance in Sub-Saharan Africa. The RSPI provides a transparent, reproducible, and evidence-based framework that can guide policymakers and stakeholders in prioritizing interventions and improving road safety outcomes across the region.

4. Results and Discussion

4.1 Overview of Results

The Road Safety Performance Index (RSPI) was applied to evaluate road safety performance across 20 Sub-Saharan African countries. The results revealed significant disparities in road safety performance, with Mauritania emerging as the top performer (RSPI score: 92.03) and Ethiopia and Nigeria ranking among the lowest. The findings highlight the critical role of factors such as road infrastructure quality, enforcement of traffic laws, and socio-economic conditions in shaping road safety outcomes.

4.2 Model Results and Statistical Analysis

4.2.1 Regression Analysis and Model Fit

The multiple regression analysis used to construct the RSPI yielded a highly significant model, as evidenced by the following key metrics:

- R-squared (R-sq): The model achieved an R-squared value of 99.91%, indicating that the selected 13 indicators explain 99.91% of the variance in road safety performance. This exceptionally high value demonstrates the model's ability to capture the underlying factors influencing road safety outcomes.
- Adjusted R-squared (R-sq(adj)): The adjusted R-squared value of 99.72% accounts for the number of predictors in the model, confirming that the model's goodness of fit is not due to overfitting.
- Predicted R-squared (R-sq(pred)): The predicted R-squared value of 97.32% suggests that the model has strong predictive capabilities, making it suitable for future applications and policy recommendations.
- All 13 indicators included in the regression model were statistically significant (p-values < 0.05), confirming their relevance in explaining road safety performance.

4.2.3 Residual Analysis and Model Diagnostics

To assess the quality of the regression model, residual analysis was conducted using Figure 1, which includes:

- Normal Probability Plot: The residuals follow a normal distribution, indicating that the model assumptions are met.
- Versus Fits Plot: The residuals are randomly scattered around zero, suggesting that the model captures the underlying relationships without systematic errors.

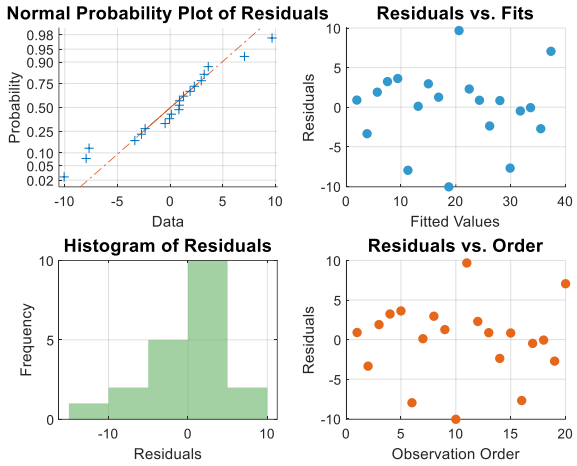

Figure 1. Residual analysis plots for regression model (equation 3): (a)normal probability plot, (b)versus fits plot, (c)residual histogram, (d)versus order plot

- Histogram: The distribution of residuals resembles a bell curve, further confirming the normality assumption.
- Versus Order Plot: No trends or patterns are observed, indicating that the residuals are independent of the order of data collection.

These diagnostic plots confirm that the regression model is well-fitted to the data and free from major issues such as nonlinearity, heteroscedasticity, or violations of normality assumptions.

4.3 In-Depth Analysis of Key Findings

4.3.1 Top Performers: Mauritania, Rwanda, and Benin

Mauritania's strong performance can be attributed to its robust road safety measures, including well-maintained road infrastructure, effective enforcement of traffic laws, and low alcohol consumption rates. These findings align with [5] WHO 2018 reports, which highlight the importance of infrastructure quality and enforcement in reducing road traffic fatalities. Similarly, Rwanda (RSPI score: 89.86) and Benin (RSPI score: 89.58) demonstrated commendable road safety performance, particularly in urban traffic management and public awareness campaigns. These results are consistent with Okafor 2013 [13], who emphasized the role of urbanization and public awareness in improving road safety in Sub-Saharan Africa.

4.3.2 Countries with Opportunities for Improvement

Ethiopia and Nigeria ranked among the lowest in the RSPI, with scores of 65.34 and 68.21, respectively. These countries face significant challenges, including poor road infrastructure, weak enforcement of traffic laws, and high rates of alcohol-related accidents. These findings are consistent with Nantulya & Reich,

2002 [10], who identified weak institutional frameworks and limited funding as major barriers to road safety in Sub-Saharan Africa. Addressing these challenges will require targeted investments in road upgrades, stricter enforcement measures, and comprehensive public awareness campaigns [3, 19].

4.2.3 Key Factors Influencing Road Safety Performance

The regression analysis revealed that several factors significantly influence road safety performance in Sub-Saharan Africa as described below and presented in figure2:

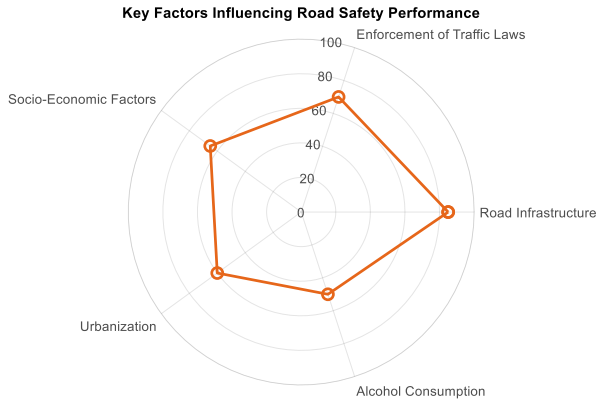

Figure 2. Main factors influencing road safety performance

- Road Infrastructure Quality: Countries with higher percentages of paved roads (IPR) and greater investments in road safety (IAI) demonstrated better road safety outcomes. This aligns with Elvik et al. (2009), who found that infrastructure improvements can significantly reduce road traffic fatalities.
- Enforcement of Traffic Laws: Countries with stricter enforcement of traffic laws, such as speed limits and drunk driving regulations, performed better in the RSPI. This is consistent with Bishai et al. (2006), who emphasized the importance of enforcement in reducing road accidents.
- Socio-Economic Factors: Higher GDP per capita (IDG) and urbanization rates (IPU) were associated with better road safety performance, as they enable greater investments in road safety measures. This finding supports Kopits and Cropper (2005), who highlighted the link between economic development and road safety outcomes.

4.4. Comparative Analysis with Other Regions

To provide a broader perspective on road safety performance, the RSPI results for Sub-Saharan Africa were compared with road safety outcomes in other regions such as Europe and Southeast Asia. The results are presented visually in Figure 3. These comparisons highlight successful interventions and best practices that could be adapted to Sub-Saharan Africa.

4.4.1 Europe

European countries generally have lower road traffic fatality rates, with an average of 8.3 deaths per 100,000 population, compared to 26.6 deaths per 100,000 in Sub-Saharan Africa. This disparity can be attributed to several factors:

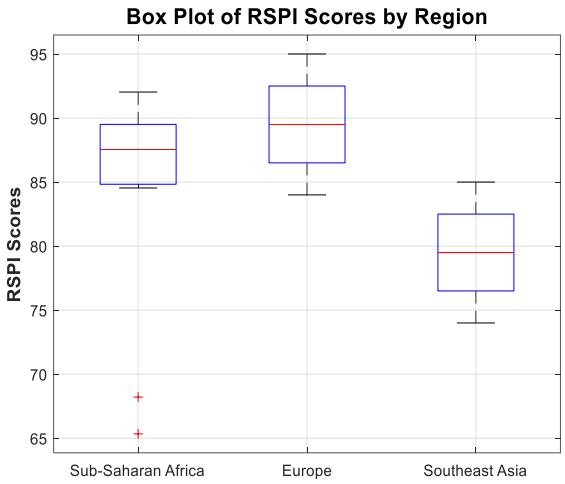

Figure 3. Comparative analysis results with other regions

- Strict Enforcement of Traffic Laws: Countries like Sweden and the Netherlands have implemented strict enforcement of speed limits, drunk driving regulations, and seat belt laws, significantly reducing road accidents. For example, Sweden's Vision Zero initiative, which aims to eliminate road fatalities, has been highly successful due to its focus on enforcement and infrastructure improvements.
- Investment in Intelligent Transportation Systems (ITS): Many European countries have invested in advanced technologies, such as traffic cameras, automated speed enforcement, and real-time traffic monitoring systems. These technologies have proven effective in reducing speeding and improving traffic flow in urban areas.
- Public Awareness Campaigns: European countries have also prioritized public awareness campaigns to educate road users about the dangers of speeding, drunk driving, and distracted driving. These campaigns have fostered a culture of road safety and responsible driving behavior.

4.4.2 Southeast Asia

Southeast Asia faces significant road safety challenges, with an average fatality rate of 20.7 deaths per 100,000 population. However, countries like Singapore and Malaysia have made notable progress through targeted interventions:

- Comprehensive Traffic Law Enforcement: Singapore has implemented strict enforcement of traffic laws, including heavy penalties for speeding and drunk driving. This has led to a significant reduction in road accidents and fatalities [20-21].
- Investment in Public Transportation: Malaysia has invested heavily in public transportation systems, such as the Kuala Lumpur Mass Rapid Transit (MRT), to reduce traffic congestion and encourage the use of safer transportation options [22-24].
- Road Safety Education Programs: Both Singapore and Malaysia have launched nationwide road safety education programs targeting schools, workplaces, and communities. These programs have raised awareness about road safety and promoted responsible road user behaviour [25-26].

4.4.3 Lessons for Sub-Saharan Africa

The success of these regions offers valuable lessons for Sub-Saharan Africa. Key interventions that could be adapted include:

- Strict Enforcement of Traffic Laws: Countries like Rwanda and Mauritania, which have strong enforcement of traffic laws, could serve as models for other Sub-Saharan African nations. Strengthening enforcement mechanisms, such as increasing the presence of traffic police and implementing automated speed cameras, could significantly reduce accidents.
- Investment in Intelligent Transportation Systems (ITS): Adopting technologies like traffic cameras, automated speed enforcement, and real-time traffic monitoring could help address speeding and congestion in urban areas.
- Public Awareness Campaigns: Launching nationwide campaigns to educate road users about the dangers of speeding, drunk driving, and distracted driving could foster a culture of road safety and reduce risky behaviors.

4.4 Visual Aids to Illustrate Key Findings

To make the findings more accessible and engaging, several visual aids were used:

Figure 4, illustrates the RSPI scores for all 20 countries, highlighting the top performers (e.g., Mauritania, Rwanda) and those with opportunities for improvement (e.g., Ethiopia, Nigeria).

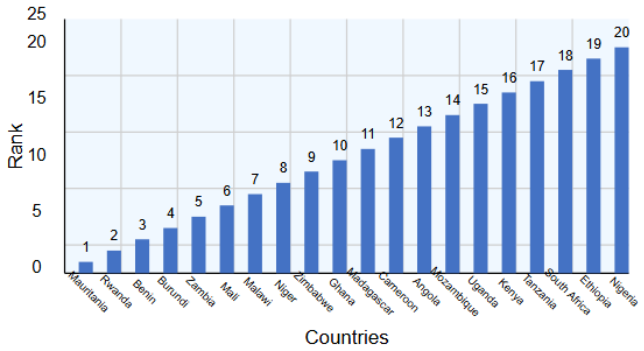

Figure 4. Ranking of countries-based road safety performance index scores

Figure 5 provides a comparative analysis of key road safety indicators, such as Road Infrastructure Quality, Enforcement of Traffic Laws, and GDP per Capita, between top-performing countries (e.g., Mauritania) and bottom-performing countries (e.g., Ethiopia). The top performers typically excel in areas like road infrastructure and law enforcement, while the bottom performers show weaknesses in these areas, highlighting opportunities for improvement. This comparison helps identify best practices and areas needing targeted interventions.

Figure 6, on the other hand, presents a correlation matrix that illustrates the relationships between road safety indicators, using colors to represent positive, negative, or neutral correlations. For example, higher GDP per Capita may correlate with better road infrastructure, while higher Alcohol Consumption may correlate with lower road safety performance. This matrix helps policymakers identify key drivers of road safety, such as enforcement and infrastructure, and prioritize interventions to address the most impactful factors. Together, these figures provide actionable insights for improving road safety outcomes across the region.

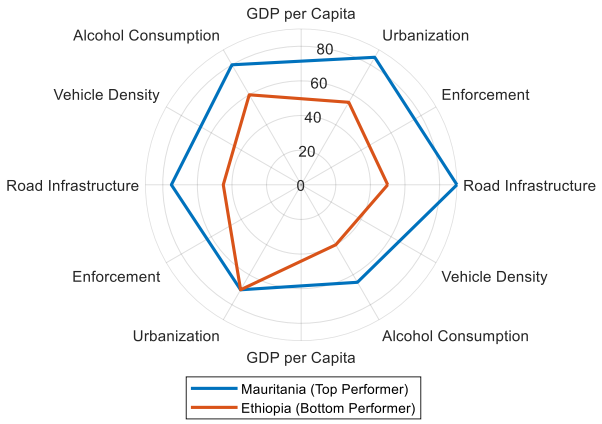

Figure 5. Comparison of key indicators for top and bottom performers

Figure 6. Correlation matrix of road safety indicators

5. Conclusions

This study developed and applied the Road Safety Performance Index (RSPI) to evaluate road safety performance across 20 Sub-Saharan African countries. The RSPI, which integrates 13 key indicators, provides a comprehensive and standardized framework for assessing road safety outcomes in the region. The results revealed significant disparities in road safety performance, with Mauritania emerging as the top performer and Ethiopia and Nigeria ranking among the lowest. Key factors influencing road safety performance include road infrastructure quality, enforcement of traffic laws, socio-economic conditions, and road user behaviour.

The regression analysis demonstrated a strong fit between the data and the proposed methodology, with an R-squared value of 99.91% and statistically significant coefficients for all indicators. This confirms the robustness of the RSPI as a tool for benchmarking road safety performance and identifying areas for improvement. The findings align with existing literature and real-world observations, underscoring the importance of targeted interventions in addressing road safety challenges in Sub-Saharan Africa.

5.1 Policy Implications

The findings of this study have significant implications for policymakers and stakeholders in Sub-Saharan Africa. Based on the RSPI results and comparative analysis, the following specific recommendations are proposed:

1. Invest in Road Infrastructure:
   - Prioritize investments in road upgrades, including paving roads, improving signage, and implementing pedestrian safety measures.
   - Focus on high-risk areas, such as urban centres and rural roads with poor maintenance, to reduce accident hotspots.
2. Strengthen Enforcement of Traffic Laws:
   - Increase the presence of traffic police and implement automated enforcement systems, such as speed cameras, to deter speeding and drunk driving.
   - Introduce stricter penalties for traffic violations, including fines, license suspensions, and mandatory road safety education programs.
3. Promote Public Awareness and Education:
   - Launch nationwide campaigns to educate road users about the dangers of speeding, drunk driving, and distracted driving.
   - Target schools, workplaces, and communities to foster a culture of road safety from an early age.
4. Adopt Intelligent Transportation Systems (ITS):
   - Invest in technologies like traffic cameras, automated speed enforcement, and real-time traffic monitoring to improve traffic management and reduce accidents in urban areas.
   - Partner with international organizations and technology providers to implement ITS solutions tailored to the region's needs.
5. Learn from Best Practices:
   - Study successful interventions from regions like Europe and Southeast Asia, such as Sweden's Vision Zero initiative and Singapore's strict enforcement of traffic laws, and adapt them to the local context.
   - Collaborate with countries like Rwanda and Mauritania, which have demonstrated strong road safety performance, to share knowledge and best practices.

By addressing these priorities, Sub-Saharan African countries can make significant progress in reducing road traffic accidents, injuries, and fatalities, ultimately creating safer and more sustainable transportation systems.

5.2 Directions for Further Studies

While this study provides valuable insights into road safety performance in Sub-Saharan Africa, several areas warrant further investigation:

1. Expanding the Scope of Indicators: Future studies could incorporate additional indicators, such as cultural factors, informal transportation systems, and the impact of climate change on road safety, to provide a more comprehensive assessment.
2. Longitudinal Analysis: Conducting longitudinal studies to track changes in road safety performance over time would provide insights into the effectiveness of interventions and policies.
3. Case Studies of Successful Interventions: In-depth case studies of countries that have successfully improved road safety (e.g., Rwanda, Mauritius) could identify best practices and lessons learned for other Sub-Saharan African countries.
4. Impact of Technology: Investigating the role of emerging technologies, such as intelligent transportation systems, vehicle safety features, and data analytics, in improving road safety outcomes could provide innovative solutions for the region.
5. Regional and Subnational Analysis: Expanding the analysis to include subnational data or regional comparisons within Sub-Saharan Africa could uncover localized challenges and opportunities for improvement.

By addressing these research gaps, future studies can build on the findings of this research and contribute to the development of evidence-based road safety policies and interventions in Sub-Saharan Africa and beyond.

Acknowledgements

The authors would like to express their gratitude to the School of Transportation Engineering and School of Civil Engineering at Southeast University, Nanjing, China, for providing the academic environment and resources necessary to conduct this research. We are also deeply thankful to the World Bank, Road Safety Facility, and International Road Federation (IRF) for making their data publicly available, which was instrumental in the development of the Road Safety Performance Index (RSPI).

Special thanks go to our colleagues and peers for their valuable feedback and discussions during the preparation of this manuscript. Finally, we acknowledge the support of our families and friends, whose encouragement and understanding made this work possible.

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