EdinBurg Peer Reviewed Journals and Books Publishers
Innovative Journal of Social Sciences (ijss)
Vol. 5||Issue 2||pp 1-12||July||2025
Email: info@edinburgjournals.org

Road Conditions and Performance of Road Safety along Outer Ring Road in Nairobi City County, Kenya

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Accepted: 12 June 2025 || Published: 05 July 2025

Abstract

Road safety remains a pressing challenge for Kenya's urban transport system, especially in Nairobi, where increased vehicle use and inadequate infrastructure have deteriorated road safety conditions. Grounded in Systems Theory, this study investigated the influence of road conditions on the performance of road safety along Outer Ring Road in Nairobi City County, Kenya. The study adopted a convergent parallel research design to collect both quantitative and qualitative data simultaneously, analyzed independently and integrated for comprehensive insights. The target population comprised 2,190 Matatu drivers drawn from seven Matatu associations, four NTSA officials, and ten KURA representatives. A sample of 338 Matatu drivers was selected using stratified and simple random sampling techniques, while 14 key informants were purposively chosen, yielding a total sample size of 352 participants. Structured questionnaires and interview guides were used for data collection. A pilot study was conducted on Jogoo Road to test validity and reliability of the tools. Quantitative data were analyzed using descriptive and inferential statistics in SPSS, while qualitative data were thematically analyzed and reported verbatim. A response rate of 90% (n=303) was achieved. The research tools demonstrated high internal consistency, with Cronbach's Alpha coefficients of 0.783 for road conditions and 0.776 for performance of road safety. Findings indicated that poor road conditions—including surface quality, signage, drainage, and lane design—significantly undermine performance of road safety along Outering Road (mean = 3.83; SD = 0.524). Key informants affirmed that deteriorated road environments elevate accident risks. Pearson correlation analysis revealed a strong, positive, and significant relationship between road conditions and performance of road safety ($r = 0.707$; $p = 0.000$). Regression analysis confirmed road conditions as a statistically significant predictor of performance of road safety (Beta = 0.073; $p = 0.000$). The study concluded that poor road conditions significantly influence the performance of road safety along Outer Ring Road. The findings underscore the urgent need for urban transport agencies to invest in road maintenance, improve signage and drainage, and upgrade lane designs to enhance road safety outcomes.

Keywords: *Road conditions, Performance of Road Safety, Outer Ring Road, Nairobi City County*

How to Cite: Tirkole, J., Silas, S. K., & Macharia, S. (2025). Road Conditions and Performance of Road Safety along Outer Ring Road in Nairobi City County, Kenya. *Innovative Journal of Social Sciences, 5*(2), 1-12.

1. Introduction

Worldwide, economic activities depend on urban transportation systems, including roads, trains, waterways, and airways (Unchanam, 2024). Among these, road networks constitute the largest share of urban transportation systems. However, performance of road safety is largely influenced by the prevailing conditions of these road networks. Road conditions such as damaged surfaces, inadequate signage, poor drainage, and limited lighting—have raised road safety concerns in China (Sadeghi & Goli, 2024). These road-related issues have visibly contributed to delays, frequent accidents, and reduced transport efficiency. Congestion often arises when deteriorated roads limit the smooth flow of vehicles, even when traffic volumes are manageable (Szele, 2021). Inadequate road conditions, rather than traffic volume alone, play a major role in impeding safe and efficient travel. Similarly, in Hangary, poor road conditions are a major contributor to the high rate of road traffic accidents, which remain a leading cause of trauma admissions (Shi et al., 2024). Substandard roads—characterized by potholes, eroded markings, and insufficient safety features—greatly increase the likelihood of crashes. In the United Kingdom poor road conditions contributed to traffic accidents that cost the economy an estimated £15 billion in 2021 (Naqvi, Quddus, & Enoch, 2023). As a result, improving road infrastructure has become a central focus of transportation policies in both developed and developing countries.

In Africa, while transportation demand and supply have grown, improvements in road conditions have not kept pace, resulting in persistent congestion and safety issues. In Nigeria, deteriorating road surfaces, narrow lanes, and poor drainage have significantly contributed to traffic congestion, negatively affecting economic productivity through the loss of work hours, increased air pollution, and heightened carbon emissions (Sani, Hassan, Musa, & Musa, 2020). In Ghana, poor road conditions have compounded the road safety crisis, with road crashes being a leading cause of fatalities (Edunyah, 2023). The worn-out roads, unclear markings, and insufficient signage exacerbate the risks as submitted in a study by Walekhwa et al. (2022) in Uganda. Similarly, in Tanzania, frequent traffic accidents are largely attributed to degraded road infrastructure, such as potholes and inadequate road design, in addition to vehicle conditions and reckless driving (Nzuchi, Ngoma, & Meshi, 2022). Despite expansions in Tanzania's road network, key corridors continue to suffer from congestion due to poor road layouts and bottlenecks, limiting commuter mobility and causing regular delays, especially during peak hours. These delays result in lost time, increased fuel consumption, and reduced economic output.

In Kenya, road transport is the primary driver of economic development and employment, with over 85% of the population relying on roads daily (Mose, 2022). However, urban roads are increasingly affected by road conditions resulting in delays, increased fuel consumption, financial losses, noise pollution, and sometimes, mortalities (Muthomi, 2023). According to the (NTSA, 2021), poor road conditions pose a serious threat to road safety, with projections indicating that the situation is likely to worsen. The agency recommended urgent government interventions such as repairing potholes, installing proper lighting, clearly marking diversions and speed bumps, and conducting regular inspections of roads and bridges. Well-maintained

and smooth highways not only improve user safety and comfort but also help reduce vehicle damage and minimize government expenditure on road maintenance and healthcare (Muguro et al., 2022).

1.1 Problem statement

Outer Ring Road was developed to enhance traffic mobility by providing a critical link between vehicles, motorists, and pedestrians to major highways. In pursuit of this objective, the Government of Kenya invested in various infrastructural and regulatory interventions. These included the construction of pedestrian sidewalks, the development of eleven footbridges, the establishment of designated pedestrian crossing zones, and the physical separation of pedestrian and vehicular lanes. Moreover, zoning regulations were implemented to control informal roadside commercial activities that often interfere with traffic flow. In addition, authorities installed technological surveillance systems such as cameras and sensors, alongside the enforcement of strict police monitoring and legal penalties aimed at curbing illegal roadside parking, speeding, and other traffic violations.

Despite various interventions, road safety along Outer Ring Road in Nairobi continues to perform poorly, with traffic violations—such as speeding, reckless driving, and driving under the influence—on the rise. Between January and October 2021, multiple fatal accidents involving pedestrians and other road users were reported along this corridor (Njagi & Obebo, 2023). Notably, Outer Ring Road accounted for 90% of its traffic fatalities through pedestrian-related incidents within eastern Nairobi (Taherpour, 2023). According to the National Transport and Safety Authority (NTSA, 2021), there has been a marked increase in traffic congestion, road crashes, and over-speeding incidents along Outer Ring Road, with injuries rising by 46.5% and fatalities by 26% between 2015 and 2021 (Muguro et al., 2022). Despite the significant social and economic consequences—including loss of life, injuries, traffic congestion, and reduced productivity—limited research has addressed this phenomenon, resulting in both empirical and conceptual knowledge gaps. To address these gaps, this study sought to examine the influence of road conditions on performance of road safety along Outer Ring Road in Nairobi, Kenya. The investigation aimed to generate evidence-based insights to inform the formulation and implementation of more effective urban transport safety strategies in Nairobi and similar urban settings.

1.2 Purpose of the study

To examine the influence of road conditions on performance of road safety along Outer Ring Road in Nairobi city, Kenya.

1.3 Research hypotheses

$H0_1$: There is no statistically significant relationship between road conditions and performance of road safety along Outer ring road in Nairobi City County, Kenya

Ha_1: There is a statistically significant relationship between road conditions and performance of road safety along Outer ring road in Nairobi City County, Kenya

2. Literature Review

2.1 Theoretical Review

Systems Theory, developed by Ludwig von Bertalanffy in 1972 (von Bertalanffy, 1972), offers a comprehensive framework for understanding how different components within a system

interact to influence overall outcomes (Poole, 2014). It emphasizes that changes in one part of a system can produce ripple effects across the entire structure, highlighting the importance of adopting a holistic, system-wide perspective for effective interventions. In the context of road safety, this approach has been valuable in analyzing complex transportation systems. For example, Chand et al. (2021) illustrated the benefits of examining the interconnections among vehicles, infrastructure, and road users. Similarly, Elvik et al. (2019) introduced the Systems Theoretic Accident Model and Processes (STAMP), emphasizing that traffic accidents often stem from broader systemic failures rather than isolated incidents. Azadani and Boukerche (2021) also demonstrated how improvements in infrastructure and traffic management can significantly influence driver behavior and reduce congestion.

However, a key limitation of the theory is its limited attention to the resource-intensive, diverse, and context-specific nature of road systems, which complicates its application and standardization across different environments (Strauss, 2002). Despite this, Systems Theory remains highly relevant for studying road conditions and safety performance. It underscores the interconnectedness of critical factors such as infrastructure, driver behavior, environmental conditions, vehicle design, and traffic regulations. Moreover, its capacity to integrate multiple stakeholder perspectives and adapt to dynamic conditions makes it particularly suited for evaluating road safety outcomes.

2.2 Empirical Review

Road safety outcomes are determined by road conditions (World Health Organization [WHO, 2023). Well-managed roads with good signage and less traffic congestion make driving safer, cutting down on accident risks, and ensuring a smooth flow of traffic in general (Bansal, 2024). This is especially true on merging lanes and road intersections, as a higher concentration of vehicles is more likely to be involved in rear-end collisions. China recorded a significant percentage of road accidents because of both driver distraction and speeding (Elvik et al., 2019). Three major factors that led to accidents included conflicts between road users together with insufficient infrastructure and absent road safety education (Truong & Currie, 2019). The combination of adverse weather conditions insufficient street illumination and complex road path design produced substantial risk increases (Imprialou & Quddus, 2019).

Road accidents during poor visibility periods as well as driver behavior and confusion and high vehicle traffic points at intersections and roundabouts substantially increased accident frequency (Odonkor et al., 2020). Ghanese drivers admit that speeding together with traffic signal noncompliance stands as the primary dangerous behaviors involved in accidents (Damsere-Derry et al., 2019). Jaywalking alongside disregarding traffic signals by pedestrians made Côte d'Ivoire collisions more likely (Cestac et al., 2019).

Bad road conditions together with deficient signage create hazardous driving areas which endanger road users in Nairobi heightening congestion and accidents (Bouraima et al., 2022). Job and Wambulwa (2020) studied driver conduct and traffic security connections at various levels in Meru, Kenya. Research findings demonstrated that traffic accidents and fatalities elevated because of quick accelerations together with close follow-ups and reckless swift passes among drivers. Traffic conflicts and road accidents increased primarily because drivers did not give way to walkers and bikers as per Kirira et al. (2019). Traffic congestion and road accidents lead to substantial economic losses because they generate higher fuel usage costs and

vehicle damages as well as medical treatment expenses and decreased productivity (Omondi & Kinoti, 2020).

3. Material and Methods

The study employed a convergent parallel research design to collect both quantitative and qualitative data separately, analyze them independently, and then converge the findings for comprehensive interpretation (Dawadi, Shrestha & Giri, 2021). The target population comprised 2,190 Matatu drivers drawn from seven Matatu associations operating along Outer Ring Road routes, alongside 14 key informants—4 officials from the National Transport and Safety Authority (NTSA) and 10 from the Kenya Urban Roads Authority (KURA). Using Sloven's formula, a sample size of 338 Matatu drivers was determined for the quantitative interviews, while all 14 key informants were selected purposively, bringing the total sample size to 352 participants. To ensure a representative sample for the quantitative component, the population was stratified into seven homogeneous strata based on Matatu associations through stratified random sampling. Proportional allocation was then applied using probability proportionate to size, and specific drivers were selected through simple random sampling within each group. Quantitative data were collected using structured questionnaires, while qualitative data were obtained through key informant interview guides. The data collection tools were piloted along Jogoo Road, chosen for its similar road conditions to Outer Ring Road. Quantitative data were analyzed using SPSS, applying descriptive statistics such as frequencies and means to summarize the data, and inferential statistics, including correlation and regression analysis, to explore relationships and predictive strength between road conditions and performance of road safety. Results were presented in tables. Qualitative data were analyzed thematically and presented verbatim to capture key insights. Throughout the research process, the study adhered to ethical standards to ensure integrity and confidentiality.

4. Results and Discussion

4.1 Response Rate

Out of the 338 structured questionnaires distributed, 303 were successfully completed and returned, yielding a high response rate of 90.0%. This strong participation may be attributed to respondents being given ample time to complete the questionnaires, as well as the study's emphasis on informed consent, which ensured confidentiality and encouraged participation (Jäckle et al., 2021). The 10% non-response rate could be linked to a lack of interest in the topic or the perceived absence of personal benefit. Additionally, out of 14 key informants approached, 11 agreed to participate in the study.

4.2 Reliability Test

The reliability test was undertaken by use of Cronbach's Alpha coefficient to measure the internal consistency of the constructs making up the scale.

Table 1: Reliability results

Variable	Cronbach's Alpha	Number of constructs	Comment
Road conditions	0.732	9	Reliable
Performance of road safety	0.763	10	Reliable

The study confirmed the reliability of the data collection tool, with Cronbach's Alpha values of road conditions (r=0.732) and performance of road safety (r=0.763). The Cronbach's Alpha coefficient of 0.7 and above indicates acceptable reliability (Ahmad et al., 2024).

4.3 Descriptive Statistics

The study employed descriptive analysis to provide a summary of the data.

Table 2: Respondents' opinion on road conditions along the Outer Ring Road in Nairobi.

Statements	Strongly Disagree	Disagree	Moderate	Agree	Strongly Agree	Mean	Std. Dev
The potholes, cracks, and ruts along Outer Ring Roads always risk our safety	2.3%	3.0%	13.9%	47.5%	33.3%	4.07	.893
The rough road surface increases the possibility of skidding car	2.3%	10.6%	16.5%	49.8%	20.8%	3.76	.975
Slippery surfaces, reduce traction and stability	0.0%	14.2%	23.4%	33.7%	28.7%	3.77	1.019
Poorly designed with sharp curves, limited visibility	3.3%	12.5%	20.8%	44.2%	19.1%	3.63	1.033
Poorly marked lanes always make driving hard along Outer Ring Road	0.7%	12.2%	25.7%	40.3%	21.1%	3.69	.961
Warning signs alert drivers to potential hazards in the roadway environment	0.7%	6.3%	20.5%	46.2%	26.4%	3.91	.880
Always, the no parking signs lead to unsafe use of Outer Ring Road	0.0%	5.0%	20.5%	44.2%	30.4%	4.00	.842
Always, poorly marked guide signs provide non-directional information	1.3%	7.9%	24.4%	36.3%	30.0%	3.86	.981
Overall Composite mean and standard deviation						**3.83**	**.524**

The findings reveal that poor road conditions significantly compromise road safety along Nairobi's Outer Ring Road (mean=3.83; SD=0.524). Surface defects such as potholes, cracks, and ruts (mean = 4.07; SD = 0.893), were reported to reduce vehicle control and increase accident risks. Skidding on rough or slippery surfaces (mean = 3.76; SD = 0.975) was also a major concern, especially during rains, attributed to poor drainage and lack of maintenance. These findings align with studies by Sadeghi and Goli (2024), which link deteriorated surfaces and inadequate drainage to higher accident risks. Furthermore, road design flaws also emerged as safety hazards. Sharp curves, poor visibility, and inadequate shoulder width were associated with run-off-road crashes and rollovers (mean = 3.63; SD = 1.033), as supported by Khan

(2024). Poor lane markings further hindered safe navigation (mean = 3.69; SD = 0.961), contributing to driver confusion and collisions, consistent with Formosa et al. (2024)). Traffic signage played a dual role: while 46.2% of respondents agreed that warning signs were effective (mean = 3.91; SD = 0.880), many cited poor route guidance signage as a challenge (mean = 3.86; SD = 0.981). This supports Desaim& Chowdhury (2024) assertion that inadequate signage contributes to driver error and road mishaps. Moreover, law enforcement was seen as moderately effective, with 49.8% agreeing that police respond quickly to incidents (mean = 3.78; SD = 0.732). However, the findings also highlight the need for enhanced responsiveness, echoing Ochieng and Ndungu's (2021) observation of delays in intervention.

Key informants highlighted that road surface defects—such as potholes and uneven patches—lead to vehicle damage and increased accident risks. KII_1 (Male, 2nd February 2025) noted, *"...Potholes and poorly maintained surfaces lead to loss of vehicle control and accidents..."* These insights align with Osoro (2024), who found that poorly maintained surfaces especially endanger motorcyclists and cyclists. Lane configuration was also identified as a major safety concern. According to KII_002 (Female, 2nd February 2025), *"...the lack of designated lanes for motorcycles further complicates lane usage and increases the likelihood of accidents..."* Consistent with Kuria (2021) findings that unclear lane configurations heighten crash risks. Furthermore, unclear signs lead to sudden maneuvers and errors; *"...inadequate signage makes it challenging for drivers to navigate, especially new motorists..."* (KII_10, Male, 4th February 2025). Nyasio (2021) similarly reported that poor signage hampers navigation and raises accident risk. Drainage problems compromise road safety, particularly during rains. KII_002 (Female, 2nd February 2025) stated, *"...flooded roads during rains reduce visibility and control..."* Kipchirchir & Moi (2023) affirmed that inadequate drainage contributes to flooding, poor visibility, and increased accident probability.

4.4 Correlation Analysis

Pearson correlation analysis was conducted to assess the magnitude and direction of the relationship between road conditions and performance of road safety.

Table 3: Correlations

Variable		Performance of Road Safety	Road conditions
Performance of Road Safety	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	303	
Road Conditions	Pearson Correlation	.707**	1
	Sig. (2-tailed)	.000	
	N	303	303

**. Correlation is significant at the 0.01 level (2-tailed).

The study established that road conditions had positive, strong and significant association with performance of road safety (r=.707; n=303; P=0.000). While the road conditions deteriorate due to potholes, poor signage, or inadequate lighting, performance of road safety is likely to decline because poor road conditions increase the likelihood of accidents by making driving

more hazardous. A significant correlation between the road conditions and road safety indicated that the relationship was robust and not likely due to chance. The findings mirrored those of World Health Organization (WHO, 2023) that road conditions, including road surface quality, signage, and maintenance, have a direct impact on road safety. Poor road conditions were linked to increased accident rates, while improved road infrastructure and maintenance were associated with better performance of road safety (Rajput, Chaturvedi & Patel, 2022).

4.5 Regression Analysis

Simple linear regression explored the predictive ability of the road conditions on road safety along Outer Ring Road. It assessed how best the model explained the total variance on dependent variable.

Table 4: Regression weights

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-2.073	.391		-5.304	.000		
	Road Conditions	.067	.011	.073	5.869	.000	.417	2.398

a. Dependent Variable: Performance of road safety

The results revealed that road conditions significantly influence performance of road safety along Outer Ring Road.

From the conventional model; $Y = \beta_0 + \beta_1 X_1 + \varepsilon$

The regression analysis produced the model:

Performance of road safety = -2.073 + 0.067(Road Conditions)

This implies that when road conditions are held constant at zero, the expected value of performance of road safety is -2.073 (β_0= -2.073; Std. Error = 0.391; t = -5.304; p = 0.000). Additionally, for every one-unit increase in poor road conditions, performance of road safety worsens by 0.067 units. This relationship was found to be statistically significant (β_1 = 0.067; Std. Error = 0.011; t = 5.869; p = 0.000), confirming that deteriorating road conditions negatively impact safety performance.

Hypothesis testing

$H0_1$: There is no statistically significant relationship between road conditions and performance of road safety along Outer Ring Road in Nairobi City County, Kenya

Ha_1: There is a statistically significant relationship between road conditions and performance of road safety along Outer Ring Road in Nairobi City County, Kenya

Decision: *The study rejected the null hypothesis (**$H0_1$**) and failed to reject the alternative hypothesis (**Ha_1**).*

5. Conclusion

The study concluded that road conditions significantly influence performance of road safety along Outer Ring Road, Nairobi City County, Kenya.

6. Recommendations

6.1 Recommendations for Practice

To improve performance of road safety, practitioners involved in road construction and maintenance should prioritize enhancing the quality of road surfaces. Regular inspections should be institutionalized to detect and repair potholes, cracks, and worn-out sections of the road. The use of durable and weather-resistant materials is essential to ensure longevity and reduce the frequency of maintenance interventions. Additionally, there is a need to redesign and improve lane configurations. Clear lane markings, sufficient lane width, and designated lanes for different categories of road users such as pedestrians, cyclists, and public service vehicles should be adopted. This would help in reducing conflicts between road users and enhance the overall flow and safety of traffic. Proper and visible road signage also plays a critical role in promoting safety. Authorities should ensure that signs are strategically placed, standardized, and made of reflective materials to enhance visibility both during the day and at night. Regular maintenance of signage is necessary to replace damaged or missing signs. Moreover, drainage systems should be efficiently constructed and regularly maintained to prevent waterlogging and flooding on the road surface. Stagnant water not only damages road infrastructure but also poses serious safety risks due to reduced traction and visibility. It is important that drainage channels are inspected and cleared frequently, especially during the rainy seasons.

6.2 Recommendations for Policy

It is imperative for the government, through the Ministry of Roads and Transport and relevant agencies such as the KURA, to develop and enforce comprehensive standards for road construction and maintenance. These standards should emphasize the need for high-quality road surfaces, effective lane designs, adequate signage, and functional drainage systems. Performance-based contracting should be considered to ensure accountability and sustained quality in road infrastructure projects. Furthermore, policies should be developed to guide the design and implementation of lane configurations in urban areas. These policies should promote the integration of inclusive road designs that cater to all users, including vulnerable groups such as pedestrians and cyclists. Such planning will foster safer and more efficient road use. A national policy framework on road signage should also be established to ensure uniformity in the design, placement, and maintenance of signs across the country. This would include adopting modern technologies such as digital signage and smart traffic management systems to enhance real-time communication with road users. Lastly, there is a need for legislation that mandates proper stormwater management in all road construction projects. The inclusion of robust drainage plans should be a prerequisite for project approval, and non-compliance should attract penalties. Such measures will help prevent road deterioration and enhance safety, particularly in flood-prone urban environments like Nairobi.

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