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

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Abstract

Traffic safety remains a critical concern for Kenyan transport authorities, particularly in urban areas where rapid population growth and vehicle use have strained existing infrastructure. Grounded in the traffic theory, the study examined the influence of traffic congestion on performance of road safety along Outer Ring Road, Nairobi. The study used a convergent parallel research design to collect both quantitative and qualitative data simultaneously, analyzed independently and triangulated. The target population comprised 2,190 Matatu drivers on Outer Ring Road, four NTSA officials, and ten KURA representatives. A sample of 338 drivers was selected through probabilistic sampling, while 14 key informants were purposively chosen, totaling 352 participants. Data were collected using structured questionnaires and interview guides. A pilot study was conducted on Jogoo Road to enhance validity and reliability of tools. Data analysis included descriptive and inferential statistics, with qualitative data analyzed thematically and reported verbatim. A 90% (n=303) response rate was achieved. The data collection instruments showed high internal consistency, with Cronbach's Alpha reliability coefficient recorded at 0.772 on traffic congestion and 0.763 for Performance of road safety constructs. Results showed that traffic congestion significantly affects road safety, fuel efficiency, and travel reliability along Outer Ring Road (mean = 3.83; SD = 0.443). Key informants confirmed these findings, citing increased travel costs and delays. Pearson correlation indicated a strong, positive, and significant link between congestion and Performance of road safety ($r = 0.987$; $p = 0.000$), while regression analysis showed congestion as the most influential factor, explaining 90.7% of the variation in safety outcomes (Beta = 0.907; $p = 0.000$). The study concluded that traffic congestion is a major determinant of performance of road safety along Outer Ring Road in Nairobi, statistically significantly influencing performance of road safety along Outer Ring Road.

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

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1. Introduction

Urban transportation systems are central to economic activity in cities worldwide, with road networks forming the backbone of most metropolitan areas (Diao, Kong & Zhao, 2021). As urban populations grow and vehicle numbers rise, road safety has emerged as a critical concern. Road safety, defined as the safe interaction between road users and their environment, is increasingly threatened by traffic congestion. Congestion occurs when the number of vehicles surpasses the carrying capacity of road infrastructure, leading to delays, reduced travel efficiency, and heightened safety risks (Afrin & Yodo, 2020).

In China, traffic congestion has become a growing concern. Rapid urbanization and increased car ownership have overwhelmed road capacities, resulting in frequent delays and heightened accident risks (Micari & Napoli, 2024). Studies show that China's deteriorating infrastructure and inadequate traffic management have exacerbated safety challenges, with congestion often linked to increased collisions and unsafe driving conditions. Similarly, high-income countries such as Great Britain report significant economic losses due to congestion-related traffic accidents. In Saudi Arabia, traffic congestion contributes to high accident rates, making road safety a top public health and policy issue (Patel, 2020; Ahmed et al., 2023). These global experiences underscore the need for urgent interventions to address traffic congestion as a key determinant of performance of road safety.

Traffic congestion has emerged as a critical challenge impacting both mobility and road safety in Africa. The imbalance between rising transportation demand and inadequate traffic management systems has led to severe congestion, particularly in urban centers. In Nigeria, traffic congestion has negatively impacted the economy by causing loss of productive hours, increased air pollution, and elevated greenhouse gas emissions (Sani, Hassan, Musa & Musa, 2020). Contributing factors include insufficient road capacity, poor traffic regulation, and poor public transportation systems, despite government interventions such as road expansions and mass transit initiatives (Aderibigbe & Olajide, 2023). In Ghana, high rates of road accidents, largely caused by human error and noncompliance with traffic laws, underscore the direct link between congestion and safety risks (Boateng, 2021). Similarly, in Tanzania, major transport corridors suffer from significant inter-city congestion, which exacerbates delays and increases accident risks due to poor road design, heavy traffic, and reckless driving behaviors (Nzuchi, Ngoma & Meshi, 2022).

In Kenya, road network carries over 85% of the population and freight, making it the backbone of national transportation (Muguro, Sasaki, Matsushita, & Njeri, 2020). However, urban traffic congestion in towns and cities continues to escalate, causing significant delays, increased fuel consumption, noise pollution, and a surge in rear-end collisions (Muguro et al., 2020). This growing congestion poses a serious threat to road safety, with projections indicating that the situation will deteriorate further, posing challenges for urban planners (Cheruiyot, 2023). Moreover, Kenya records an average of 3,000 traffic-related fatalities annually, with many more sustaining injuries—some from severe accidents involving entire families (Muguro et al., 2022). These accidents have devastating social and economic impacts. Ensuring better road conditions and infrastructure—such as well-maintained surfaces, clear signage, effective intersection design, and adequate lane layout—has become crucial to improving performance of road safety and minimizing both vehicle damage and associated public health costs.

1.1 Problem Statement

Outer Ring Road was built to ease traffic mobility by connecting vehicles, motorists, and pedestrian to the highways in the eastern part of Nairobi. The government integrated land-use planning by offering pedestrian sidewalks, police enforcement to ensure no illegal driving, and construction of 11 footbridges. Despite the investments, the National Transport and Safety Authority (NTSA) reported multiple fatal accidents on Outer Ring Road from January to October 2021 and pedestrians suffered the most casualties (Njagi & Obebo, 2023). This road claims 90% of its victims through pedestrian fatalities every year (Taherpour, 2023). The annual numbers of traffic violations which include speeding alongside reckless driving and driving under the influence have increased during the same period.

Moreover, Outer Ring Road was identified as one of the most unsafe highways globally in a United Nations high-level meeting on road safety. The combination of poor infrastructure, risky pedestrian behavior, and inadequate safety measures continues to make Outer Ring Road a hazardous route for commuters. Despite the fact that this phenomenon has a significant influence on deaths, congestion, and economic losses, minimal research has been done to comprehend it. As a result, the study sought to examine the influence of urban traffic-flow characteristics on performance of road safety along Outer Ring Road in Nairobi City, Kenya.

1.2 Purpose of the study

The study sought to establish the influence of traffic congestion on Performance of road safety along Outer Ring Road in Nairobi city, Kenya.

1.3 Research hypotheses

H_{01}: There is no significant relationship between traffic congestion and performance of road safety along Outer Ring Road in Nairobi City County, Kenya

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

2. Literature Review

2.1 Theoretical Review

Traffic Flow Theory was established in the 1930s by Greenshields, Herman, and Wardrop (Wardrop, 1952). The theory explains the interrelationships among traffic speed, density, and flow rate, providing a mathematical framework for understanding traffic behavior and its impact on road safety (Herman et al., 1959). The theory posits that traffic flow increases with density up to a critical point, after which congestion sets in and flow declines. Greenshields introduced a linear model connecting speed and density, while Herman and Wardrop expanded the theory by incorporating factors like driver behavior and road design (Ahn et al., 2019). Contemporary studies, such as those by Hossain (2015) and Ren (2018), have applied the theory to analyze fuel consumption, accident risk, and environmental impact.

However, the theory is critiqued in the nature of reliance on simplified assumptions and idealized conditions limits real-world accuracy. The theory often struggles with the complexity and variability of actual traffic environments. Despite this, the theory is applicable in the study as it links traffic volume, speed, and density to congestion and performance of road safety. It supports the analysis of how traffic congestions influence safety outcomes and helps guide effective traffic management and infrastructure planning aimed at reducing congestion.

2.2 Empirical review

Traffic congestion adversely affects road safety by increasing the likelihood and severity of accidents while also delaying emergency response times, which can worsen injury outcomes and fatalities. Congestion induces aggressive driving behaviors, such as speeding and risky maneuvers, which elevate accident risks. Research from Canada by Pires et al. (2020) highlights that congestion significantly raises operational costs for commercial vehicles and commuters alike, with the average driver incurring an additional $1,500 annually due to delays. Stop-and-go traffic increases fuel consumption, raising operational expenses and contributing to environmental pollution (Anil, 2024). Accident severity is higher in congested conditions because limited space and driver reaction time hinder safe evasive actions (Afrin & Yodo, 2020).

Traffic congestion causes significant increases in travel costs and fuel consumption, straining both individual commuters and commercial operations. In Nigeria, each 10% increase in congestion results in a 5% rise in travel expenses due to higher fuel use, extended travel times, and increased vehicle maintenance (Odusola et al., 2023). Major urban centers such as Accra and Kumasi suffer from severe congestion, compounded by side friction effects from pedestrians, street vendors, and roadside activities, which reduce road capacity and heighten accident risks (Hart, 2019; Bokaba et al., 2022). Traffic congestion not only increases travel expenses but also escalates environmental pollution, calling for robust traffic management systems and the promotion of sustainable transport alternatives (Lwesya et al., 2021).

In East Africa, growing urban populations and inadequate infrastructure intensify congestion's impact on travel costs and road safety. Congestion prolongs journey times, increases fuel consumption, and raises the risk of collisions, particularly during peak periods when traffic volumes surge (Faheem, Shorbagy & Gabr, 2024). Efficient traffic management solutions and investments in public transportation are crucial to mitigate these challenges, improving both economic efficiency and environmental sustainability.

In Nairobi, Kenya, congestion significantly increases travel expenses as commuters spend more time on the road and consume more fuel, with peak period costs averaging 30% higher than off-peak and, in some cases, doubling (Kipchirchir, 2023). Research shows a direct correlation between congestion and increased gasoline consumption, with fuel use rising by approximately 25% during heavy traffic (Gachie, 2022). Moreover, peak traffic periods see higher fatal accident rates due to reduced maneuverability and multi-vehicle collisions (Sule, 2021). These trends highlight the urgent need for improved traffic management, better infrastructure, and enforcement of road safety measures in Kenyan urban centers.

3. Materials and Methods

The study was conducted along Outer Ring Road, employing convergent parallel research design, that enable collection of both quantitative and qualitative data simultaneously, analyzed independently and converged for a comprehensive understanding. The target population included 2,190 Matatu drivers operating along Outer Ring Road. Furthermore, four NTSA officials and ten KURA representatives were included as key informants because NTSA officials play a vital role in enforcing traffic regulations, managing road safety policies, providing national accident data, offering authoritative insights into the causes and impacts of traffic congestion and accidents. Meanwhile, KURA representatives oversee the planning, construction, and maintenance of urban roads like Outer Ring Road, contributing essential

technical and operational expertise on road infrastructure and traffic flow management to support efforts in improving road safety.

A sample of 338 drivers was selected through probabilistic sampling: stratified random sampling was used to group the population into homogenous strata, with proportional sampling to allocate the population in respective strata and simple random selection used to choose participants randomly. Additionally, 14 key informants were purposively selected for interviews, bringing the total sample to 352. Structured questionnaires and interview guides facilitated data collection. A pilot study was conducted along Jogoo Road to test the validity and reliability of the tools. Quantitative data were analyzed using descriptive statistics (percentiles, standard deviations) to summarize the data. Inferential techniques, including Pearson correlation and multiple regression, were used to assess the relationship between variables and predictive ability of the independent variables on the dependent variables, respectively. Qualitative data underwent thematic analysis and were presented through verbatim responses, enriching the interpretation of statistical results and supporting the study's overall findings.

4. Results and Discussion

4.1 Response Rate

A total of 338 structured surveys were spread to the respondents, with 303 completed, yielding a 90.0% response rate. The data collection tool demonstrated strong reliability, with a Cronbach's Alpha coefficient of 0.772 for traffic congestion and 0.763 for performance of road safety constructs. A Cronbach's Alpha (r) value of 0.7 and above is generally considered reliable and acceptable for research purposes (Forero, 2024).

4.2 Descriptive Statistics Analysis

The study investigated the influence of traffic congestion on performance of road safety along the Outer Ring Road, Nairobi with four characteristics: travel costs, fuel consumption, lateral friction, and travel time.

Table 1: Respondents' opinions on traffic congestion along the Outer Ring Road, Nairobi

Statements	Strongly Disagree	Disagree	Moderate	Agree	Strongly Agree	Mean	Std. Dev
We always face delays during travel times along the Outer Ring Road	1.0%	4.3%	15.8%	53.5%	25.4%	3.98	.822
I always face difficulties when rescheduling trips	1.7%	0.7%	25.7%	50.5%	21.5%	3.89	.799
I rarely use alternative travel modes	0.0%	1.3%	7.3%	64.4%	27.1%	4.17	.606
I always cause tailpipe pollution	0.7%	1.0%	37.0%	43.2%	18.2%	3.77	.775
I always experience frequent stop-and-go driving along Outer Ring Road	1.0%	4.3%	15.8%	53.5%	25.4%	3.98	.822
I rarely experience idling along Outer Ring Road which consumes fuel without contributing to forward movement	1.0%	0.0%	34.0%	49.8%	15.2%	3.78	.732
I always experience lower fuel efficiency along Outer Ring Road	5.0%	28.4%	34.7%	21.5%	10.6%	3.04	1.059
Always, I operate at higher engine loads	0.7%	14.5%	27.1%	44.6%	13.2%	3.55	.919
I always change lanes frequently to navigate around slower-moving vehicles, merge with traffic, or exit the roadway	0.0%	6.6%	29.7%	51.2%	12.5%	3.70	.772
I hardly experience weaving movements to avoid traffic jams along Outer Ring Road, Nairobi City County.	1.3%	0.7%	23.1%	48.2%	26.7%	3.98	.803
I always encounter reduced maneuverability while driving along Outer Ring roads, in Nairobi City County.	0.0%	0.7%	7.9%	58.4%	33.0%	4.24	.617
Overall Composite mean and standard deviation						**3.83**	**.443**

The findings indicated that traffic congestion along Outer Ring Road, Nairobi, significantly impaired road safety, fuel efficiency, and travel reliability (aggregate mean=3.83; SD=0.443). Most respondents (79%) agreed that congestion caused frequent delays, longer commute times, and travel uncertainties that affected productivity and emergency responses. There was a heavy reliance on private transport (over 90% agreement), reflecting limited public transport options. Stop-and-go traffic was a common issue, contributing to increased fuel consumption, vehicle maintenance costs, and emissions. Many respondents (57%) acknowledged higher engine loads and frequent lane changing, both of which disrupted traffic flow and elevated accident risks. Reduced maneuverability due to congestion was a major challenge, reported by over 90% of respondents, increasing accident likelihood and delays. Despite this, nearly 75% indicated

some controlled traffic movement with limited weaving to avoid jams, suggesting partial adherence to traffic rules.

The key informants' responses aligned with the statistical findings, confirming that traffic congestion along Outer Ring Road in Nairobi significantly impacted performance of road safety through increased travel costs, fuel consumption, lateral friction, and prolonged travel times. One respondent noted, *"…Traffic congestion significantly increases travel costs due to longer journey times and higher fuel consumption…"* (KII_001, Male, 2nd February 2025), consistent with Gikonyo and Karanja (2023), who found fuel consumption notably higher during congestion, burdening public transport operators and private vehicle owners.

Lateral friction from increased conflicts among road users was highlighted as a major safety concern, with informants noting, *"…increased friction from merging and diverging traffic raises the risk of side-swipe accidents…"* (KII_002, Female, 2nd February 2025), aligning with Mwangi and Ochieng (2021) who linked lateral friction in congested areas to higher side-swipe accident rates. Reckless overtaking and unpredictable matatu stop also raised accident risks: *"…Matatus stopping randomly to pick passengers…"* (KII_006, Female, 3rd February 2025) and "…Reckless overtaking increases accident risk…" (KII_007, Male, 3rd February, 2025).

Prolonged travel times were reported to cause *"…driver fatigue and stress, leading to risky behaviors like speeding or overtaking, which compromise road safety…"* (KII_011, Male, 4th February 2025), consistent with Wambui et al. (2022) who emphasized fatigue and stress during peak hours increase aggressive driving. Another key informant noted that average travel time "has doubled during peak hours, impacting productivity and safety" (KII_001, Male, 2nd February 2025), leading to *"…unpredictable delays making travel planning difficult…"* (KII_008, Female, 4th February 2025).

4.3 Correlation Analysis

Bivariate Product Moment Pearson correlation analysis was conducted to assess the magnitude, direction, and significance of the relationship between traffic congestion and performance road safety along Outer Ring roads.

Table 2: Correlations

Variable		Performance of Road Safety	Traffic Congestion
Performance of Road Safety	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	303	
Traffic Congestion	Pearson Correlation	.987**	1
	Sig. (2-tailed)	.000	
	N	303	303

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

The study found that traffic congestion had a strong, positive, and significant association with the Performance of road safety along Outer Ring Road, Nairobi (r=0.987; n=303; P=0.000).

This implied that if more traffic congestion is associated with worse performance of road safety, then road safety deteriorates as congestion worsens. The relationship between congestion and road safety was statistically significant meaning that the observed relationship is unlikely to be due to random chance but based on the data. Similarly, Muthomi (2023) did a study on the application of GIS in Mediating Traffic Congestion in Central Business Districts. The study found a direct correlation between traffic congestion and accident rates, suggesting that congested roads lead to slower response times for emergency services, heightened driver frustration, and poor decision-making, all of which contribute to a higher incidence of road traffic injuries.

4.4 Regression Analysis

Simple linear regression was conducted to explore the predictive ability of the traffic congestions on road safety along Outer Ring roads.

Table 3: Regression coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-2.125	.394		-5.390	.000		
	Traffic Congestion	.842	.012	.907	70.153	.000	.388	2.574

a. Dependent Variable: Performance of road safety

The study found that traffic congestion (Beta = 90.7, t = 70.820; p = 0.000) had a strong and statistically significant influence on performance of road safety. The findings imply that traffic congestion is a critical predictor of road safety outcomes along Outer Ring Road in Nairobi. From a policy and planning perspective, this underscores the need to prioritize congestion mitigation to improve safety. Prolonged travel times, stop-and-go conditions, increased lateral friction, and erratic driver behavior contribute to higher accident rates, reduced fuel efficiency, and accelerated vehicle wear, ultimately increasing economic burdens due to delays, medical expenses, and lost productivity. The findings are consistent with prior research by Gunjo, Guta, and Damene (2024), who found that higher congestion levels were positively associated with increased crash frequency and severity in urban settings in Addis Ababa, Ethiopia due to the rise in traffic conflicts and driver frustration. Conversely, the findings disagreed with those of the World Health Organization (WHO, 2023) that under certain conditions, moderate congestion may reduce severe crashes because vehicles travel at lower speeds, thereby minimizing the impact of collisions and enhancing pedestrian safety.

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

The resulting regression model was: Performance of road safety = -2.073+.842 (Traffic Congestion)

This implied that when traffic congestion, is at zero, the expected value of Performance of road safety is -2.073 (β_0= -2.073; Std. Error =.391; t-value =-5.304; Sig.= .000). While, for every one-unit increase in Traffic Congestion, performance of road safety worsened by 0.842 units, $p < 0.05$ ($\beta 1$= .842; Std Error =.012; t-value=70.820; P= .000).

5. Conclusion

The study concluded that traffic congestion has a negative and statistically significant influence on performance of road safety along Outer Ring Road in Nairobi. As congestion increases, road safety conditions worsen, indicating that traffic congestion is a major contributor to unsafe road environments. The findings highlight the importance of addressing congestion through effective traffic management and comprehensive urban transport planning strategies to enhance road safety and reduce accident risks. This supports the need for targeted interventions that can ease traffic flow, improve driver behavior, and create safer conditions for all road users.

6. Recommendations

6.1 Recommendations for Practice

Urban transport planners and enforcement agencies should implement practical measures to ease congestion along Outer Ring Road. These may include synchronized traffic signals, dedicated bus lanes, improved signage, and deployment of more traffic officers during peak hours. Additionally, promoting alternative transport modes such as non-motorized transport and other public transit modes use, can help reduce vehicle volume and enhance road safety.

6.2 Recommendations for Policy

Policymakers should formulate and enforce comprehensive urban mobility policies that prioritize congestion management and road safety. This includes reviewing zoning regulations to reduce traffic generators, investing in intelligent transport systems technology (ITS) to increase the capacity of busy roads, reduce journey times, enable the collection of information on unsuspecting road users and establishing congestion charges or vehicle restrictions during peak hours. Policy frameworks should also support infrastructure development tailored to accommodate growing urban populations while ensuring road safety

6.3 Recommendations for Theory

The findings support the theoretical link between urban congestion and road safety, reinforcing traffic flow and behavioral theories that associate increased congestion with poor safety outcomes. Future research should expand theoretical models by incorporating contextual urban dynamics such as informal transport systems, enforcement effectiveness, and road user behavior. This would deepen understanding and improve the predictive power of traffic safety theories in developing urban contexts.

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