Internet-of-Things and Performance of Road Safety Management in Nairobi County, Kenya

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Abstract

Road safety continues to pose a significant challenge in Nairobi County, Kenya, with persistent cases of traffic accidents, congestion, and emergency response inefficiencies resulting in substantial loss of life and economic costs. This study sought to examine the influence of Internet of Things (IoT) technologies on the performance of road safety management in Nairobi County. Specifically, the study evaluated the effects of driver behavior monitoring, smart traffic infrastructure, vehicle-to-vehicle (V2V) communication, and IoT-based vehicle assistance technologies on key road safety outcomes. The study was anchored on four theories: the Technology Acceptance Model (TAM), Diffusion of Innovation Theory, the Socio-Technical Systems (STS) theory, and the Systems Theory. This study adopted a descriptive research design. The target population comprised 655 key stakeholders in road safety management, including traffic police officers, insurance companies, emergency service providers, and technology firms. The sample size of 248 respondents was determined using Yamane's formula (1967). A purposive sampling technique was employed to ensure proportional representation of all stakeholder categories. Primary data were collected using structured questionnaires, while secondary data was sourced from policy documents, NTSA reports, and scholarly articles. The questionnaire was pre-tested on 25 individuals excluded from the final sample to ensure validity and reliability. Cronbach's alpha was used to assess internal consistency, and all constructs recorded coefficients above the 0.7 threshold. Data was analyzed using the Statistical Package for Social Sciences (SPSS) version 26.0. Descriptive statistics, including means, standard deviations, and frequency distributions, were used to summarize the data, while inferential analysis, including Pearson correlation and regression analysis, was used to test the relationships between variables. Qualitative data from open-ended questions were analyzed thematically. The findings revealed that smart traffic infrastructure significantly enhanced traffic flow and safety, while driver behavior monitoring technologies were associated with improved compliance and reduced risky driving. V2V communication significantly reduced collision rates, and IoT-based vehicle assistance tools contributed to better navigation and decreased congestion. Overall, the integration of IoT technologies had a statistically significant positive influence on road safety management in Nairobi County ($r = 0.743$, $p = 0.000$). The study concludes that IoT presents a transformative opportunity to enhance urban road safety through real-time data exchange, predictive analytics, and intelligent automation. The study recommends increased investment in IoT infrastructure and policy frameworks to support widespread adoption. Further research is recommended to explore the long-term impact of IoT on road safety in other urban settings and assess the cost-effectiveness of various IoT applications in traffic management.

Keywords: *Internet-of-Things, Performance, Road Safety Management, Nairobi County, Kenya*

1.0 Background of the Study

Road traffic injuries remain a major global public health concern, causing severe human and economic losses. The World Health Organization reported 1.35 million annual deaths from road crashes and more than 50 million non-fatal injuries, many resulting in lifelong disabilities (WHO, 2022). Low- and middle-income countries experience over 93% of these fatalities despite having far fewer vehicles than high-income countries (World Bank, 2023). This disparity reflects structural weaknesses in enforcement, infrastructure, and behavioral compliance. The growing burden of road injuries places pressure on health systems, reduces productivity, and intensifies poverty cycles. The global urgency to reduce fatalities underscores the need for innovative, technology-driven solutions capable of supporting monitoring, prevention, and real-time management.

The Internet of Things (IoT) offers a modern pathway for improving road safety by enabling interconnected devices to collect, process, and transmit real-time information. IoT applications in road safety include smart traffic lights, vehicle-to-vehicle communication, automated alerts, predictive analytics, and sensor-based road monitoring (Zhang et al., 2020). These technologies enhance hazard detection, streamline enforcement, and improve decision-making among transport stakeholders. Real-time surveillance systems have demonstrated the capacity to reduce violation rates, ease congestion, and identify high-risk areas faster than traditional methods. Such innovations support early intervention, minimize accident severity, and improve emergency responsiveness. As urbanization intensifies and traffic volumes rise, IoT becomes essential for achieving safer and more efficient road transport systems.

Globally, IoT integration has gained traction in intelligent transportation systems, with countries such as Singapore, Japan, Sweden, and the United States demonstrating strong outcomes. Singapore's adaptive traffic systems optimize traffic flow using live sensor data and significantly reduce intersection collisions (Fantin et al., 2022). The Netherlands' smart highways integrate dynamic lighting and temperature-sensitive road surfaces to enhance visibility and mitigate weather-related risks (Jansen, 2022). In the United States, vehicle-to-vehicle pilots have enhanced situational awareness and reduced crash probability (Spears, 2022). These experiences illustrate the transformative potential of IoT in improving safety, enforcing compliance, and strengthening mobility. They also provide a benchmark for countries seeking scalable and evidence-based digital transport solutions.

Across Africa, IoT adoption is growing gradually, with countries such as South Africa, Nigeria, and Egypt implementing sensor-based monitoring, automated enforcement, and smart traffic control (Muthoni, 2022; Kobayashi, 2023). South Africa's telematics systems have reduced risky driving behaviors by monitoring speeding, fatigue, and harsh braking. Nigeria has deployed smart cameras and IoT-enabled traffic lights to address congestion and improve compliance (Okoro & Nwosu, 2019). Egypt's New Administrative Capital integrates IoT-driven traffic monitoring and smart parking to optimize mobility (Bhattacharya et al., 2022). Despite these gains, limited funding, weak digital infrastructure, and technical skills gaps slow widespread adoption (Andersson, 2021). Even so, the continent's high fatality rates make IoT an important option for strengthening accident prevention and emergency response.

In Kenya, road traffic injuries continue to rise, with urban counties such as Nairobi experiencing the highest burden. NTSA reported more than 4,690 road fatalities in 2022, driven by poor infrastructure, congestion, human error, and inadequate enforcement (NTSA, 2024). IoT technologies offer significant opportunities for improving safety by enabling continuous monitoring, automated alerts, and data-driven enforcement. Smart sensors, GPS-enabled

tracking, and fatigue-detection wearables can support timely interventions and reduce high-risk behavior (Kamau & Wanjiru, 2023). Connected vehicle systems have potential to reduce collisions at intersections and improve pedestrian safety (Kumar et al., 2019). These innovations align with Kenya's Vision 2030 reforms aimed at strengthening public safety and modernizing transport networks (Moyo & Banda, 2021).

The National Transport and Safety Authority (NTSA) plays a central role in regulating transport, improving enforcement, and coordinating safety programs. Initiatives such as the digital driving licence, smart PSV monitoring, and the demerit point system are designed to enhance compliance and reduce risky behavior (Wanjiru, 2021). Despite these efforts, weaknesses persist due to infrastructure deficits, corruption, and inconsistent enforcement (Mulaa, 2023). Rapid growth in vehicle numbers and continued congestion in Nairobi further strain NTSA's capacity (Munyao, 2022). Integrating IoT within NTSA's operations could enhance real-time monitoring, improve targeting of violators, and strengthen institutional accountability. As Kenya continues to urbanize, sustainable and technologically enabled safety systems become increasingly necessary.

Although IoT had shown strong potential for enhancing road safety globally, local evidence in Nairobi County remained scarce and fragmented. Previous studies did not adequately assess how multiple IoT systems collectively influenced safety performance, nor did they evaluate stakeholder readiness, operational barriers, or contextual factors shaping adoption. There was also limited empirical analysis linking IoT technologies to measurable safety outcomes such as reduced collisions, improved compliance, or enhanced response times. This thesis therefore addressed these gaps by examining how driver behavior monitoring systems, road infrastructure technologies, communication systems, and vehicle assistance technologies affected road safety management in Nairobi County. The study provided evidence to guide policy formulation, investment decisions, and large-scale IoT deployment within Kenya's transport sector.

1.1 Statement of the Problem

Kenya's road infrastructure plays a pivotal role as the gateway to East Africa, serving as a crucial transit hub for cargo and people across the region (Wanjiru, 2021). However, despite significant development projects like the Nairobi Expressway and the expansion of major highways, the infrastructure is still marred by insufficient signage and other safety measures, contributing to a high rate of road accidents. The newly developed expressways and highways, while boosting connectivity, often lack adequate road markings and signals, posing serious risks to drivers unfamiliar with these roads. Additionally, poorly maintained feeder roads and limited pedestrian walkways exacerbate the dangers for all road users, particularly pedestrians, who are among the most vulnerable. This infrastructural gap highlights the need for improved planning and investment to ensure that these developments enhance safety, not just connectivity (Mulaa, 2023).

Kenya's roads, while vital for its economy, present numerous risks to various groups, including pedestrians, matatus (public service vehicles), and cargo transporters (Mbugua & Ndegwa, 2023). Pedestrians face grave dangers as they navigate roads that often lack proper footpaths and pedestrian crossings, especially in high-density urban areas like Nairobi. Matatus, known for their aggressive driving habits, are involved in a large percentage of accidents, contributing to the chaotic nature of Kenya's public transport system. Cargo vehicles also pose significant risks, with overloaded trucks frequently contributing to accidents due to mechanical failures or loss of control, particularly on steep or poorly maintained roads. According to NTSA (2024),

these risks have created a dangerous environment for road users, exacerbating Kenya's road safety crisis.

Statistics reveal the grim reality of road safety in Kenya. In 2022 alone, traffic accidents claimed over 4,000 lives, marking a 15% rise in fatalities compared to the previous year (NTSA, 2023). This figure increased to over 4,500 traffic-related deaths in 2023, further highlighting the severity of the situation (KNBS, 2023). Pedestrians, who account for nearly 40% of these fatalities, are disproportionately affected, particularly in Nairobi where the lack of sufficient pedestrian infrastructure exacerbates the risks (Kamau & Wanjiru, 2023). The economic impact is equally alarming, with road traffic injuries costing Kenya approximately 1.5% of its Gross Domestic Product (WHO, 2022), underscoring the urgent need for effective interventions in road safety management.

The escalating road accidents in Kenya are not just a result of reckless driving but also poor road design and inadequate enforcement of traffic regulations. The Nairobi Expressway, despite being a modern infrastructure marvel, has seen accidents due to high-speed limits, insufficient signage, and a lack of proper safety barriers (Munyao, 2022). These risks, combined with minimal driver education and lax enforcement of traffic laws, contribute to the overall increase in road fatalities. To mitigate these issues, it is essential for Kenya to implement stricter traffic regulation enforcement, improve road infrastructure, and enhance driver awareness. Addressing these challenges is critical to reducing the number of accidents and ensuring that the country's road networks contribute positively to both economic growth and public safety (Mulaa, 2023). Although there is significant potential in utilizing Internet of Things (IoT) technologies to enhance road safety, the literature on this application remains scarce and mixed.

IoT technologies, such as smart traffic signals and vehicle-to-everything (V2X) communication systems, have shown promise in improving road safety in various international contexts (Smith & Lee, 2021). Further, research on the implementation and effectiveness of these technologies in Kenya is limited, with few studies specifically addressing their potential in Nairobi County (Mbugua & Ndegwa, 2023). The available literature often presents inconclusive results, reflecting varying degrees of success in different settings and highlighting the need for further investigation (Odera & Karanja, 2023). Given the increasing road safety challenges in Nairobi and the potential benefits of IoT technologies, there is an urgent need to explore how these innovations can be effectively applied to improve road safety outcomes in Kenya.

1.2 Objectives of the Study

   i. To assess the effect driver behavior monitoring systems on performance of road safety management in Nairobi County.
   ii. To evaluate the effect of road infrastructure technologies on performance of road safety management in Nairobi County.
   iii. To investigate the effect of communication systems on performance of road safety management in Nairobi County.
   iv. To analyze the effect of vehicle assistance technologies on performance of road safety management in Nairobi County.

2.0 Literature Review

This section discusses the various theories that the study was be anchored on, the conceptual framework, and the empirical review. The section also contains the critique of the literature, the summary of the review and the evident research gaps.

2.1 Theoretical Framework

This study was guided by four theories namely the Technology Acceptance Model (TAM), Diffusion of Innovation Theory, Socio-Technical Systems Theory and Systems Theory.

2.1.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model was developed by Fred Davis in 1986 to explain how individuals adopt and use new technologies (Davis, 1986). The theory states that perceived usefulness and perceived ease of use determine behavioral intention, assuming that users evaluate how a technology improves performance and how simple it is to operate (Na et al., 2022; Katebi et al., 2022). TAM further assumes that technology adoption is shaped by user attitudes, cognitive evaluations and expectations of improved efficiency. It also assumes that behavior arises from rational assessment rather than external enforcement. Additional studies show that organizational support and system accessibility strengthen the intention to adopt digital systems (Natasia et al., 2022). TAM emphasizes that users embrace technologies when benefits outweigh effort and complexity. It also argues that intuitive interfaces, adequate training and reliable system functionality increase the likelihood of adoption across stakeholder groups. The theory highlights that poorly designed systems, low digital literacy and unclear value propositions weaken acceptance. TAM further notes that supportive resource structures and compatibility with user tasks enhance confidence in digital tools. This theory informed the driver behavior monitoring and communication systems variables by explaining how perceived usefulness and ease of use shaped stakeholder willingness to adopt IoT technologies in Nairobi's road safety management.

2.1.2 Diffusion of Innovation Theory

Diffusion of Innovation Theory was introduced by Everett Rogers in 1962 to explain how new ideas and technologies spread within social systems (Rogers, 1962). The theory states that innovations diffuse through five stages—knowledge, persuasion, decision, implementation and confirmation—assuming that adoption increases as individuals accumulate information and observe successful use cases (Call & Herber, 2022). It further assumes that innovation adoption follows a predictable pattern influenced by early adopters, communication channels and perceived advantages (Goh & Sigala, 2020). The theory also recognizes that compatibility, trialability and observability shape willingness to embrace new technologies. Diffusion Theory emphasizes that early adopters influence wider acceptance by demonstrating outcomes, reducing uncertainty and validating the effectiveness of innovations. It also argues that adoption accelerates when innovations align with user needs, integrate smoothly into existing workflows and produce visible benefits. The theory additionally suggests that social norms, leadership support and organizational readiness determine adoption rates across populations. This theory informed the road infrastructure technology and communication systems variables by explaining how IoT solutions spread among drivers, traffic managers and enforcement agencies in Nairobi's road safety environment.
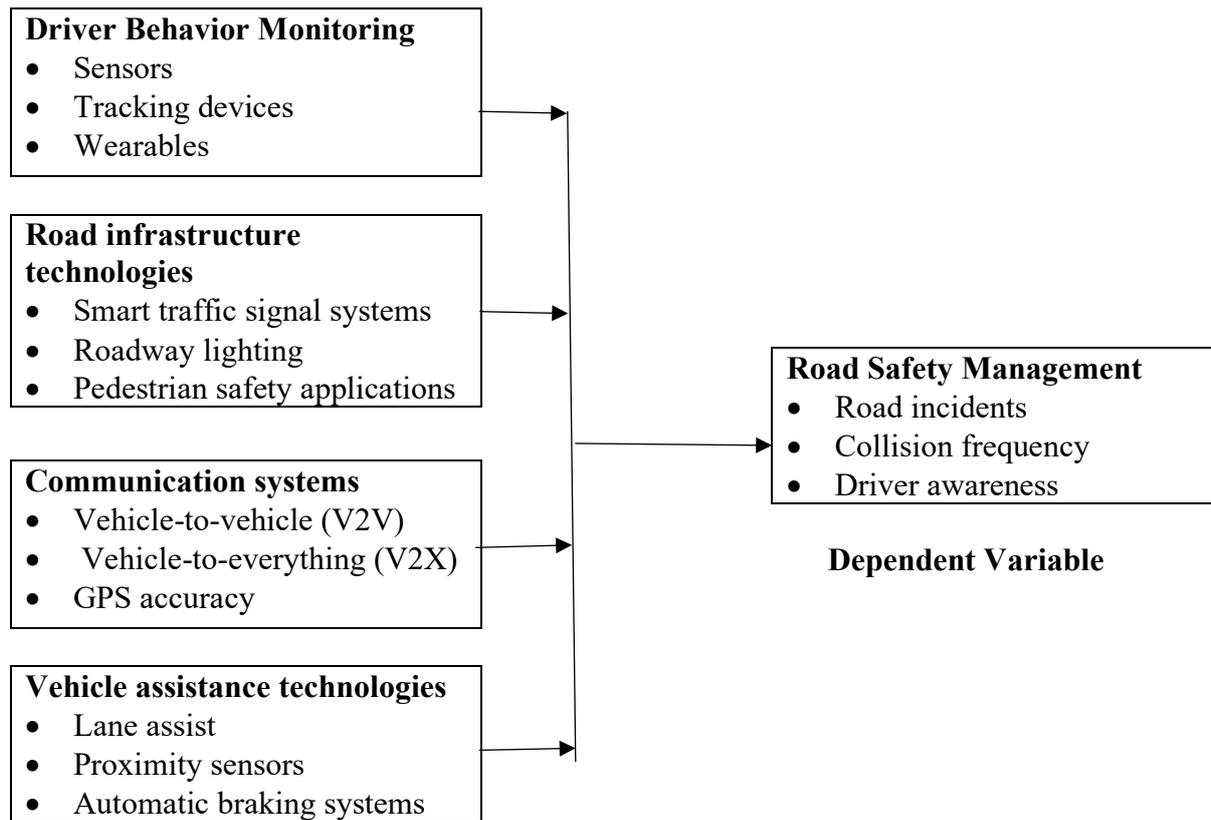
2.1.3 Socio-Technical Systems Theory (STS)

Socio-Technical Systems Theory was developed by Eric Trist and colleagues at the Tavistock Institute in the 1950s after early studies of work redesign in British coal mines (Trist & Bamforth, 1951). The theory states that organizations function through the joint interaction of social systems (people, values, skills, structures) and technical systems (tools, machines, technologies) and that both must be optimized together for effective performance (Emery & Trist, 1960; Cherns, 1976). STS assumes that technology and human behavior are interdependent and that improvements in one component require alignment with the other (Guest et al., 2022). It also assumes that participation, communication and decentralized decision-making enhance system effectiveness (Mumford, 2006). STS emphasizes that technological solutions succeed when users understand, support and integrate them into their workflows. It also argues that poorly coordinated systems, limited training or resistance to change undermine the benefits of new technologies. The theory further highlights that compatibility between human needs and technological design is essential for sustained performance. This theory informed the vehicle assistance and driver behavior monitoring variables by explaining how IoT systems required alignment between technical capabilities and human stakeholder readiness within Nairobi's road safety management.

2.1.4 Systems Theory

Systems Theory was developed by Ludwig von Bertalanffy in the 1940s to explain how components within a system interact to achieve shared objectives (Bertalanffy, 1968; Becvar et al., 2023). The theory states that systems operate holistically and that subsystems are interconnected through information flows and feedback mechanisms. It assumes that changes in one component influence the entire system, and that coordination, communication and adaptation are essential for stability (Khan et al., 2023). Systems Theory also assumes that well-aligned structures reduce duplication, strengthen control functions and promote efficient responses to disturbances. The theory emphasizes that performance improves when system elements function cohesively rather than in isolation. It also argues that disruption in one subsystem-such as driver behavior or traffic signal coordination-can destabilize the broader safety environment. Systems Theory highlights that unified platforms, transparent information flows and synchronized processes produce stronger system-wide outcomes. This theory informed the road safety performance variable by demonstrating how IoT-enabled monitoring, communication and infrastructure technologies interact to enhance efficiency, coordination and accident reduction across Nairobi's road safety management system.

2.2 Conceptual Framework

A conceptual framework in a study refers to a structured, visual or narrative representation that outlines the key variables, concepts, and their relationships within the research (Creswell, 2017). It serves as a guide to explain how the study's independent variables influence the dependent variable(s) and how different factors interrelate. Figure 1 shows the conceptual framework for the study.

Driver Behavior Monitoring
- Sensors
- Tracking devices
- Wearables

Road infrastructure technologies
- Smart traffic signal systems
- Roadway lighting
- Pedestrian safety applications

Communication systems
- Vehicle-to-vehicle (V2V)
- Vehicle-to-everything (V2X)
- GPS accuracy

Vehicle assistance technologies
- Lane assist
- Proximity sensors
- Automatic braking systems

Road Safety Management
- Road incidents
- Collision frequency
- Driver awareness

Dependent Variable

Independent Variables

Figure 1: Conceptual Framework

2.3 Empirical Review

Studies consistently show that IoT-enabled driver behavior monitoring enhances safety. In the United States, Smith et al. (2017) used a two-year longitudinal design on 200 fleet vehicles and found a 23% drop in accidents after providing telematics-based feedback on speeding and harsh braking. Similarly, Chen and Wang (2019) used biometric data from 300 Chinese commercial drivers and recorded a 15% reduction in fatigue-related incidents through wearables that issued drowsiness alerts. In Nigeria, Okonkwo et al. (2020) applied a quasi-experimental design and observed a 30% reduction in speeding among bus drivers using telematics. South African research by Moyo and Banda (2021) on 150 buses showed a 20% decline in accidents through IoT coaching systems. Kenyan studies by Mwangi et al. (2022) and Omollo et al. (2024) also demonstrated 25% and 18% reductions respectively in unsafe driving. Despite these encouraging results, long-term user acceptance, sustainability, and integration with wider traffic systems remain unaddressed.

Empirical evidence shows that IoT-enabled road infrastructure technologies significantly reduce accidents. Hernandez et al. (2018) examined adaptive traffic signals in Barcelona and found a 28% reduction in intersection crashes. In Tokyo, Matsuda and Kato (2020) evaluated IoT-enabled smart roadway lighting and recorded a 32% decline in night-time accidents. In Addis Ababa, Abebe and Mekonnen (2019) studied sensor-based pedestrian safety systems and found pedestrian incidents reduced by 22% near smart crosswalks. Nkosi et al. (2021) in Johannesburg recorded a 25% drop in congestion-related accidents after deployment of IoT traffic systems. Kenyan research by Kariuki et al. (2022) and Wanjala and Otieno (2023)

showed 19% and 21% declines respectively in pedestrian and intersection accidents after installing sensor-equipped crosswalks and adaptive traffic lights. Despite this progress, issues relating to cybersecurity, maintenance costs, and system reliability during outages remain insufficiently explored.

Communication technologies have also demonstrated strong safety benefits. In South Korea, Lee and Park (2017) monitored 500 connected vehicles for 18 months and found V2V communication reduced rear-end collisions by 35%. Jones and Cooper (2019) in the UK tested V2X communication in London intersections and recorded a 28% fall in intersection crashes. In Lagos, Adeyemi et al. (2020) documented a 20% reduction in route-related accidents using GPS-enabled communication among 200 public buses. In Zambia, Mutale and Zulu (2021) found V2I systems reduced intersection crashes by 23% after integrating vehicles with smart traffic signals. Kenyan studies by Kimani et al. (2022) and Otieno & Achieng (2023) reported 19% and 25% reductions in matatu and boda boda incidents respectively after adopting V2V and GPS-enhanced navigation. Gaps remain regarding standardization, interoperability, and the impact of poor network coverage on communication accuracy.

IoT-enabled vehicle assistance systems have been widely validated for improving safety. In Germany, Harrison and Smith (2018) analyzed 300 lane-assist-equipped vehicles and found a 27% decrease in lane departure accidents. In Shanghai, Chen et al. (2020) used mixed methods with 500 vehicles and recorded a 30% drop in rear-end collisions through proximity sensors. Nigerian research by Okoro and Nwosu (2019) showed automatic braking systems reduced taxi collisions by 22% in Abuja. In Zimbabwe, Ndlovu and Dube (2021) found a 25% decline in public bus accidents using combined lane assist and proximity systems. Kenyan studies by Mwangi et al. (2022) and Otieno & Kamau (2023) recorded 19% and 23% declines in side-impact and abrupt-stop accidents respectively. Notable gaps include cost barriers, durability concerns in harsh road conditions, and limited research on driver over-reliance on automation.

Across Africa, studies emphasize the potential of IoT but highlight persistent infrastructural and socio-economic constraints. Abebe and Mekonnen (2019), Adeyemi et al. (2020), Mutale and Zulu (2021), and Ndlovu and Dube (2021) consistently found reductions in accidents ranging from 20% to 25% across Ethiopia, Nigeria, Zambia, and Zimbabwe. Kenyan studies—including Mwangi et al. (2022), Kariuki et al. (2022), Kimani et al. (2022), and Otieno & Kamau (2023)—also consistently reported safety improvements between 19% and 25%. While these studies confirm IoT's value, they remain fragmented, often addressing single technologies rather than integrated systems. They also rarely examine scalability, policy readiness, interoperability, or stakeholder acceptance, which are crucial for sustained impact.

Existing empirical studies confirm that IoT technologies—driver monitoring, smart infrastructure, communication, and vehicle assistance—consistently improve road safety, often reducing accidents by 15%–35% across various contexts. However, most studies focus on high-income countries or isolated IoT components, limiting applicability to Nairobi's distinct traffic environment. Few studies examine long-term adoption, cost-benefit dynamics, or the influence of poor connectivity and system maintenance. Moreover, user acceptance, cultural adaptation, data privacy, and interoperability challenges remain largely unexplored. Critically, no reviewed study holistically investigated how multiple IoT technologies jointly influence road safety management in Nairobi County, creating a clear empirical gap that justified the current study.

3.0 Research Methodology

This study adopted a descriptive research design to examine how Internet of Things (IoT) technologies influence road safety management in Nairobi County, consistent with the guidance of Mugenda and Mugenda (2008). The design enabled the researcher to collect quantifiable data on IoT-enabled systems without manipulating variables, using individual respondents from technology firms, emergency response providers, insurance companies, and traffic police as the units of observation, while the organizations they represented formed the unit of analysis. The target population comprised 655 stakeholders, including 150 Intelligent Transportation Systems (ITS) providers, 50 emergency service providers, 55 insurance company personnel, and 400 traffic police officers. These groups were included due to their direct involvement in IoT deployment, accident monitoring, policy implementation, and risk assessment. The sampling frame covered organizations actively engaged in technology development, emergency response, insurance risk analysis, and traffic law enforcement. From this population, a sample of 248 respondents—ITS providers (57), emergency service providers (19), insurance officers (21), and traffic police (151)—was proportionally selected. Purposeful sampling was used to target senior professionals such as CTOs, engineers, paramedic unit heads, underwriting managers, and enforcement commanders with relevant expertise in IoT adoption and road safety operations.

Data collection involved structured questionnaires administered physically and online, complemented by secondary data gathered from NTSA reports, policy documents, and organizational publications. Questionnaires used Likert-scale items to quantify perceptions of IoT effectiveness, while secondary data supported contextual understanding of road safety trends. Prior to data collection, the researcher secured approval from JKUAT and participating institutions to comply with ethical requirements. All data were cleaned, coded, and analyzed using SPSS Version 26. Descriptive statistics summarized respondent characteristics and variable distributions, while correlation and regression analyses determined relationships among IoT-based driver behavior monitoring, infrastructure technologies, communication systems, and vehicle assistance technologies. Secondary data underwent content analysis to identify patterns relevant to road safety performance. A multiple regression model—$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$—was applied to assess the predictive influence of IoT components on road safety management outcomes in Nairobi County, ensuring a rigorous and structured interpretation of both quantitative and qualitative findings.

4.0 Data Analysis, Findings and Discussions

This chapter covers the response rate of the study, descriptive statistics and the inferential statistics.

4.1 Response Rate

The study targeted 248 respondents from the total target population of 655 respondents as presented in Table 1

Table 1: Response Rate

Category	Frequency	Percentage
Responded	194	78.2%
Not responded	54	21.8%
Total	248	100%

The study achieved a response rate of 78.2%, with 194 out of 248 respondents participating. This rate is considered satisfactory for research of this nature, providing a reliable basis for

analysis. Comparable studies, such as those by Wanjiku (2016), reported similar response rates, indicating consistent engagement levels in research on road safety management.

4.2 Descriptive Statistics

This section presents descriptive statistics aligned with the study's objectives. The data is primarily summarized using the mean, representing central tendency, and the standard deviation, indicating variability. A five-point Likert scale was employed for data analysis, with response ratings categorized as follows: where; 1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree

4.2.1 Driver Behavior Monitoring Systems

The first objective of the study was to assess the influence of driver behavior monitoring systems on road safety management in Nairobi County as presented in Table 2

Table 2: Descriptive Statistics for Driver Behavior Monitoring Systems

Statement	N	Mean	Std. Dev
IoT-based driver monitoring improves compliance with road safety rules.	194	4.5103	0.69966
IoT tracking systems help in identifying reckless driving behaviors.	194	4.5258	0.54995
Real-time driver monitoring enhances road safety and reduces accidents.	194	4.3557	0.53120
Automated driver alerts encourage safer driving habits.	194	4.5515	0.70522
IoT-based driver scoring helps insurance companies assess risk better.	194	4.2680	0.89923
The use of IoT-enabled monitoring reduces cases of distracted driving.	194	4.0979	0.95803
Average	**194**	**4.3849**	**0.52037**

The findings from Table 2 reveal that respondents largely agreed on the positive impact of IoT-based driver behavior monitoring systems on road safety. The statement with the highest mean score (M = 4.5515, SD = 0.70522) was that automated driver alerts encourage safer driving habits. This suggests that real-time, system-generated warnings are perceived as effective tools for improving on-road behavior, corroborating findings by Sharma and Patel (2021), who noted that automated alerts significantly reduce instances of speeding and lane violations. Similarly, the high mean for the statement that IoT tracking systems help in identifying reckless driving behaviors (M = 4.5258, SD = 0.54995) underscores the respondents' belief in the diagnostic utility of these technologies, aligning with results from Al-Kahtani *et al.* (2020), which demonstrated how GPS-enabled telematics have led to a measurable drop in traffic infractions.

In addition, the statement that IoT-based driver monitoring improves compliance with road safety rules recorded a strong mean of 4.5103 (SD = 0.69966), reinforcing the view that surveillance technologies act as deterrents to traffic rule violations. This supports earlier research by Kimathi (2019), who found that drivers aware of continuous monitoring systems showed a 27% improvement in adherence to road rules. Real-time driver monitoring also received a favorable rating (M = 4.3557, SD = 0.53120), suggesting that its proactive nature plays a critical role in accident prevention. This is consistent with the study by Tang *et al.* (2022), which reported that real-time IoT dashboards led to a 15% reduction in fleet-related

accidents among commercial drivers. These findings indicate a high level of trust in IoT's role in real-time behavioral correction and compliance reinforcement.

However, relatively lower mean scores were observed in statements that reflect broader or more long-term effects of IoT monitoring. The item on IoT-based driver scoring to help insurance companies assess risk better had a mean of 4.2680 (SD = 0.89923), suggesting mixed perceptions about its accuracy or fairness. This aligns with the concerns raised in a study by Njeri and Odhiambo (2020), which pointed out that drivers were skeptical of telematics-based scoring models due to potential biases and lack of transparency in algorithmic assessments. The lowest rated statement was on IoT-enabled monitoring reducing cases of distracted driving (M = 4.0979, SD = 0.95803), perhaps reflecting doubts about the system's capacity to detect subtle or short-lived distractions, such as glancing at mobile phones. These views correspond with findings by Singh and Wambua (2018), who highlighted that while IoT monitoring can detect gross negligence, it may struggle with nuanced cognitive distractions, thus limiting its efficacy in certain contexts. Overall, the average mean score for the driver behavior monitoring variable stood at 4.3849, indicating a strong consensus among respondents regarding its positive impact on road safety management in Nairobi County.

4.2.2 Road Infrastructure Technologies

The second objective of the study was to determine the effect of IoT-enabled road infrastructure technologies on road safety management in Nairobi County as shown in Table 3

Table 3: Descriptive Statistics for Road Infrastructure Technologies

Statement	N	Mean	Std. Dev
IoT-based traffic lights improve traffic flow and safety.	194	4.1804	1.14874
Smart road sensors help in identifying accident-prone areas.	194	4.1546	0.59949
IoT technologies contribute to better road maintenance and management.	194	4.2216	0.77349
Intelligent transport systems (ITS) enhance overall road safety.	194	4.3196	0.91103
IoT-based pedestrian monitoring systems improve safety for road users.	194	4.5206	0.67685
IoT-integrated road signage enhances driver awareness and compliance.	194	4.1289	1.13306
Average	**194**	**4.2543**	**0.66757**

The findings indicated that respondents generally perceive IoT-driven infrastructure systems as significantly beneficial to road safety and traffic management. The statement that received the highest mean score (M = 4.5206, SD = 0.67685) was that IoT-based pedestrian monitoring systems improve safety for road users. This highlights growing confidence in the role of smart surveillance and sensor technologies in protecting vulnerable road users, particularly in urban environments. These findings are in line with a study by Chen *et al.* (2021), which found that pedestrian safety systems using infrared and AI-enhanced cameras reduced pedestrian-related accidents by 30% in high-risk zones. Similarly, the statement that intelligent transport systems (ITS) enhance overall road safety had a high mean of 4.3196 (SD = 0.91103), reflecting a broad consensus on the value of integrating transport networks with smart technologies for real-time data sharing and decision-making, as supported by studies like Gkritza and Mannering (2020), which linked ITS implementation to measurable decreases in congestion and accident rates.

Moderate mean scores were recorded in statements related to specific infrastructure elements such as IoT-based traffic lights (M = 4.1804, SD = 1.14874) and IoT-integrated road signage (M = 4.1289, SD = 1.13306). While these means still indicate general agreement, the relatively high standard deviations suggest some variability in respondent perceptions, possibly due to inconsistent deployment or maintenance of these systems in Nairobi County. This interpretation is consistent with a study by Mutuku and Nyambura (2019), which observed that while smart traffic control systems improved traffic flow in some urban centers, their effectiveness was hampered in areas lacking robust infrastructural support or reliable internet connectivity. Similarly, the slightly lower rating for IoT road signage may reflect challenges in public awareness, interface clarity, or driver engagement with digital signage platforms.

Other components such as the use of smart road sensors to identify accident-prone areas (M = 4.1546, SD = 0.59949) and IoT's contribution to road maintenance and management (M = 4.2216, SD = 0.77349) were also well-rated, demonstrating an acknowledgment of their strategic value in long-term infrastructure planning and safety. The findings align with research by Taneja and Anand (2022), which demonstrated that road surface condition monitoring using IoT sensors enabled proactive interventions and minimized the risk of infrastructure-related accidents. Overall, the average mean score of 4.2543 reflects strong endorsement of IoT-enabled road infrastructure technologies, suggesting that respondents perceive these systems as vital to a modern, safe, and efficient urban transport ecosystem. Nonetheless, the variation in standard deviations across items points to the need for more consistent implementation and public education on the functionalities of these smart systems.

4.2.3 Communication Systems

The third objective of the study was to examine the influence of IoT-based communication systems on road safety management. The results are presented in Table 4

Table 4: Descriptive Statistics for Communication Systems

Average	**194**	**4.2543**	**0.66757**
IoT-based communication improves response times for accidents.	194	4.3866	0.62754
Real-time vehicle-to-vehicle (V2V) communication reduces road collisions.	194	4.3247	0.86540
IoT-enabled traffic alerts help in congestion management.	194	4.5155	0.55033
Emergency response coordination is enhanced through IoT-based systems.	194	4.2680	0.69812
IoT-supported data sharing improves road safety policies.	194	4.3041	0.67162
IoT-based public notifications enhance driver and pedestrian awareness.	194	4.5619	0.59252
Average	**194**	**4.3935**	**0.51778**

The findings revealed a strong positive perception among respondents regarding the role of IoT-based communication in enhancing road safety. The highest-rated item was that IoT-based public notifications enhance driver and pedestrian awareness, with a mean of 4.5619 (SD = 0.59252). This suggests widespread agreement that real-time alerts and public safety notifications disseminated through IoT networks—such as digital road signs, mobile alerts, and public broadcast systems—play a crucial role in reducing accidents and improving road user behavior. This aligns with the findings of Li *et al.* (2020), who noted that smart communication channels significantly reduced accident frequency in areas where drivers and pedestrians

received early warnings about hazards and traffic changes. Such systems contribute not only to situational awareness but also foster a more informed and responsive road environment.

Another highly rated statement was that IoT-enabled traffic alerts help in congestion management (M = 4.5155, SD = 0.55033), reflecting strong confidence in the effectiveness of real-time traffic updates in minimizing delays and reducing the likelihood of accidents caused by traffic build-up or sudden stops. Similarly, the statement on IoT-based communication improving response times for accidents received a high mean score of 4.3866 (SD = 0.62754), emphasizing the importance of fast, coordinated responses during emergencies. These findings mirror the results of research by Sharma and Choudhary (2021), which indicated that emergency communication platforms built on IoT infrastructure reduced average emergency response times by 25% in smart city trials. The relatively low standard deviations across these items suggest a high level of consensus among respondents.

While still positive, some aspects of IoT communication systems were rated slightly lower. For instance, the statement that emergency response coordination is enhanced through IoT-based systems had a mean of 4.2680 (SD = 0.69812), and the item on IoT-supported data sharing improving road safety policies had a mean of 4.3041 (SD = 0.67162). These slightly lower means may indicate that while respondents recognize the value of back-end communication and data integration for long-term planning, such impacts are less immediately visible compared to real-time alerts or emergency interventions. Nonetheless, the item on real-time vehicle-to-vehicle (V2V) communication reducing road collisions had a mean of 4.3247 (SD = 0.86540), suggesting moderate but meaningful agreement. This is in line with recent findings by Park *et al.* (2022), who demonstrated that although V2V systems hold strong potential to prevent collisions, their effectiveness in practice is currently limited by uneven adoption and technological compatibility issues. Overall, the average mean score of 4.3935 indicates strong endorsement of communication systems powered by IoT as a critical enabler of road safety and efficient traffic management.

4.2.4 Vehicle Assistance Technologies

The fourth objective was to determine the influence of IoT-based vehicle assistance technologies on road safety management in Nairobi County presented in Table 5

Table 5: Descriptive Statistics for Vehicle Assistance Technologies

Statement	N	Mean	Std. Dev
IoT-based vehicle diagnostics improve vehicle safety.	194	4.2990	0.67777
Smart braking and lane assistance reduce accident risks.	194	4.5000	1.11164
IoT-integrated vehicle emergency response systems save lives.	194	4.3402	0.52673
Automated vehicle systems improve road safety and driving experience.	194	4.0258	0.64732
IoT-enabled navigation systems enhance safer driving.	194	4.5979	0.54173
IoT-supported parking assistance reduces congestion and accidents.	194	3.9072	0.93390
Average	**194**	**4.2784**	**0.51362**

The analysis demonstrates a generally high level of agreement among respondents on the safety-enhancing potential of IoT-driven vehicle support systems. The highest-rated item was that IoT-enabled navigation systems enhance safer driving, which recorded a mean of 4.5979

and a relatively low standard deviation of 0.54173. This indicates a strong consensus that navigation technologies—such as GPS systems integrated with real-time traffic and hazard data—significantly reduce driving errors and improve situational awareness. These findings are consistent with previous research by Singh *et al.* (2021), which emphasized that real-time, IoT-enhanced navigation systems contributed to better route planning, reduced exposure to high-risk zones, and ultimately led to fewer traffic accidents. The high ratings confirm the crucial role of digital guidance in modern vehicular safety.

Additionally, the statement that smart braking and lane assistance reduce accident risks scored a mean of 4.5000, though with a notably higher standard deviation of 1.11164. While the mean suggests strong agreement, the higher variance implies some variation in respondents' experiences or perceptions—possibly due to differing exposure to or availability of these advanced driver-assistance systems (ADAS). Likewise, IoT-based vehicle diagnostics were positively rated (M = 4.2990, SD = 0.67777), reflecting respondents' confidence in systems that automatically detect mechanical faults or maintenance issues before they escalate into road hazards. This echoes the conclusions drawn by Zhou and Wang (2020), who found that predictive vehicle diagnostics significantly lowered the incidence of mechanical-related accidents by enabling pre-emptive servicing and maintenance.

On the lower end of the spectrum, IoT-supported parking assistance received the lowest rating, with a mean of 3.9072 and a higher standard deviation of 0.93390. While still above average, the lower score may reflect limited visibility or perceived value of parking systems in relation to overall road safety, particularly in regions where parking technologies are not yet widely adopted. Similarly, the statement that automated vehicle systems improve road safety and driving experience yielded a mean of 4.0258 (SD = 0.64732), suggesting moderate agreement but less enthusiasm compared to more direct safety interventions like braking or navigation aids. These results align with findings from a study by Khan *et al.* (2022), which reported that user trust in full vehicle automation remains relatively low due to concerns over reliability and control. Overall, the average mean score of 4.2784 underscores a strong belief in the effectiveness of vehicle assistance technologies, especially those that directly assist with navigation, braking, and diagnostics, in contributing to safer road environments.

4.2.5 Road Safety Management

The general objective of the study was to examine the relationship between internet of things and performance of road safety management in Nairobi County, Kenya as presented in Table 6

Table 6: Descriptive Statistics for Road Safety Management

Statement	N	Mean	Std. Dev
IoT-based systems have reduced road accidents in Nairobi County.	194	3.8608	0.81196
The use of IoT has improved emergency response times.	194	4.2113	0.72817
IoT-supported data analysis has enhanced road safety policies.	194	4.6649	0.47323
IoT-based technologies improve traffic management and enforcement.	194	4.5670	0.49677
Investment in IoT technologies should be increased for road safety.	194	4.9175	0.27580
IoT integration has increased compliance with traffic regulations.	194	4.2680	0.72720
Average	**194**	**4.4149**	**0.41184**

The findings revealed a high overall agreement among respondents on the positive impact of IoT-based systems in Nairobi County. The most highly rated item was the statement that investment in IoT technologies should be increased for road safety, which received an exceptional mean score of 4.9175 and a remarkably low standard deviation of 0.27580. This overwhelming consensus suggests that stakeholders are not only aware of the value that IoT systems bring to road safety but also strongly endorse scaling up these technologies. These findings resonate with global research by Li *et al.* (2021), who emphasized that strategic investment in smart transportation infrastructure leads to measurable improvements in road safety outcomes and regulatory compliance, especially in urban settings where traffic complexity is high.

Another highly rated item was IoT-supported data analysis has enhanced road safety policies, with a mean of 4.6649 and a standard deviation of 0.47323. This suggests that the analytical capabilities offered by IoT technologies, such as real-time data collection, trend analysis, and predictive modelling, are seen as instrumental in shaping effective and evidence-based safety policies. This is consistent with findings by Alam and Rho (2020), who argued that cities leveraging IoT for policy development witnessed better resource allocation, risk mapping, and enforcement strategies. Closely related was the statement that IoT-based technologies improve traffic management and enforcement, which also garnered a high mean of 4.5670 (SD = 0.49677), reflecting strong belief in the technologies' ability to streamline operations like automated ticketing, signal control, and surveillance.

In contrast, the statement that IoT-based systems have reduced road accidents in Nairobi County received the lowest mean score of 3.8608, with a relatively higher standard deviation of 0.81196. This indicates a more cautious or varied perception among respondents about the direct impact of IoT technologies on accident reduction. The slightly lower score may stem from ongoing challenges in Nairobi's road network or the uneven deployment of smart technologies across the county. Similar concerns were raised by Kamau and Wairimu (2019), who noted that while IoT frameworks have promising capabilities, their real-world effectiveness in Kenya is still constrained by infrastructural, institutional, and behavioral limitations. Overall, the average mean score of 4.4149 reflects a generally strong perception that IoT significantly contributes to road safety management, particularly through policy formulation, compliance, emergency response, and advocacy for greater investment.

4.3 Inferential Statistics

Inferential statistics were used to draw conclusions and make predictions about the broader population based on sample data, allowing for hypothesis testing and offering insights to support decision-making, policy formulation, and future research directions

4.3.1 Correlation Analysis

Correlation analysis was conducted in a study to examine the degree to which two variables are related thereby providing insights into potential associations that can support conclusions, guide policy decisions, or inform further analysis.

Table 7: Correlation Analysis

		Performance of Road Safety Management	Driver Behavior Monitoring Systems	Road Infrastructure Technologies	Communication Systems	Vehicle Assistance Technologies
Performance of Road Safety Management	Pearson Correlation	1.000				
	Sig. (2-tailed)					
	N	194				
Driver Behavior Monitoring Systems	Pearson Correlation	.608**	1.000			
	Sig. (2-tailed)	0.000				
	N	194	194			
Road Infrastructure Technologies	Pearson Correlation	.724**	.871**	1.000		
	Sig. (2-tailed)	0.000	0.000			
	N	194	194	194		
Communication Systems	Pearson Correlation	.661**	.836**	.844**	1.000	
	Sig. (2-tailed)	0.000	0.000	0.000		
	N	194	194	194	194	
Vehicle Assistance Technologies	Pearson Correlation	.683**	.774**	.833**	.883**	1.000
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	
	N	194	194	194	194	

The correlation analysis presents a strong and statistically significant positive relationship between IoT-related technologies and the performance of road safety management in Nairobi County. All independent variables exhibited significant Pearson correlation coefficients at the $p < 0.01$ level. Notably, road infrastructure technologies had the strongest correlation with road safety performance ($r = 0.724$), highlighting the critical role of smart infrastructure such as IoT-based traffic lights, pedestrian monitoring systems, and intelligent road signage in enhancing safety outcomes. These findings align with the research of Yang *et al.* (2022), who observed that smart infrastructure significantly improves accident prevention and response efficiency in urban traffic systems.

The second strongest correlation was found between vehicle assistance technologies and road safety management ($r = 0.683$). This suggests that technologies like smart braking systems, IoT-enabled navigation, and automated emergency responses play an essential role in reducing traffic incidents and enhancing the driving experience. This relationship mirrors findings by Singh and Vasudevan (2021), who established that IoT-supported vehicle automation contributes to decreased accident rates and better compliance with safety protocols. It reinforces the need for continued investment in vehicle-level IoT systems to support macro-level road safety goals.

Communication systems also showed a significant correlation with road safety performance (r = 0.661), confirming the importance of real-time data exchange in preventing accidents and improving response coordination. This supports the conclusions of Wang *et al.* (2020), who found that IoT-enabled V2V and V2I (vehicle-to-infrastructure) communication reduces congestion and collision rates by improving driver awareness and enhancing traffic flow control. The finding underlines how digital communication platforms can serve as a backbone for responsive, data-driven road safety management strategies.

Driver behaviour monitoring systems had the lowest, though still substantial, correlation coefficient (r = 0.608) with road safety performance. This suggests that while IoT-driven behavioural tracking (such as monitoring for fatigue, distraction, or reckless driving) contributes meaningfully to safety, it might require integration with other systems (e.g., enforcement tools or insurance incentives) to fully realize its impact. These results are comparable to those of Kassem *et al.* (2019), who noted that driver monitoring systems are most effective when combined with corrective feedback loops and policy enforcement.

Lastly, the high intercorrelations among all the independent variables (ranging from r = 0.774 to r = 0.883) indicate a high degree of interdependence between IoT technologies. For instance, communication systems and vehicle assistance technologies showed the highest correlation (r = 0.883), emphasizing that advancements in one domain (e.g., communication) often drive improvements in another (e.g., vehicle safety). These multicollinear relationships, while theoretically expected in integrated IoT environments, suggest that holistic and interoperable IoT strategies are essential for optimizing road safety management. This aligns with the systemic perspective proposed by Cagliano *et al.* (2021), advocating for unified platforms rather than fragmented IoT applications in transport safety initiatives.

4.3.2 Regression Analysis

Regression analysis was conducted to examine the relationship between a dependent variable and one or more independent variables.

Table 8: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.743[a]	0.552	0.542	0.27869	2.216

The model summary indicates a strong overall relationship between the independent variables and the dependent variable. The model's R value of 0.743 suggests a strong positive correlation, while the R Square value of 0.552 means that approximately 55.2% of the variation in road safety performance can be explained by the four IoT-based technological predictors. However, 44.8% of the variation in road safety performance remains unexplained by the current model, implying the influence of other factors not captured in this study. The adjusted R Square of 0.542 accounts for the number of predictors and confirms the model's robustness. The Durbin-Watson statistic of 2.216 falls within the acceptable range (1.5 to 2.5), indicating no serious autocorrelation issues among the residuals, and thus supporting the reliability of the regression model.

Table 9: ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	18.056	4	4.514	58.118	.000[b]
Residual	14.680	189	0.078		
Total	32.736	193			

The ANOVA results further affirm the significance of the regression model. The F-statistic value of 58.118 with a corresponding significance level (p-value) of 0.000 implies that the model is statistically significant, meaning the independent variables collectively have a significant impact on the dependent variable. This validates that the application of IoT technologies in various domains of road safety contributes meaningfully to enhancing overall road safety management. The relatively low residual mean square value (0.078) also indicates a good model fit, suggesting the predicted values closely align with actual observations.

Table 10: Model Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.316	0.199		11.658	0.000
Driver Behavior Monitoring Systems	-0.139	0.085	-0.176	-1.632	0.104
Road Infrastructure Technologies	0.374	0.072	0.606	5.214	0.000
Communication Systems	0.067	0.097	0.084	0.685	0.494
Vehicle Assistance Technologies	0.193	0.089	0.241	2.166	0.032

Road infrastructure technologies emerged as the most significant and impactful predictor of road safety management, with a standardized beta coefficient of 0.606 and a highly significant p-value (p = 0.000). This implies that improvements in smart infrastructure, such as IoT-enabled pedestrian systems, road signage, and intelligent transport systems, have the greatest influence on enhancing safety outcomes. These results support findings by Zhang and Li (2022), who demonstrated that smart infrastructure deployment significantly reduces traffic-related fatalities and improves regulatory compliance.

Vehicle assistance technologies also had a significant positive effect on road safety, with a standardized beta of 0.241 and a p-value of 0.032, suggesting that features like automated braking, emergency response systems, and intelligent navigation systems enhance driver safety and reduce accident risks. These findings are aligned with those of Singh and Vasudevan (2021), who emphasized that semi-autonomous vehicle functions integrated with IoT systems improve reaction times and reduce human error, contributing to improved traffic outcomes.

On the contrary, driver behavior monitoring systems had a negative and statistically non-significant impact (β = -0.176, p = 0.104), suggesting that while conceptually valuable, such

systems may not yet be sufficiently advanced or properly implemented in Nairobi to directly enhance road safety outcomes. It's possible that these tools lack real-time enforcement integration or are not widely adopted. This contrasts with studies in more technologically advanced regions, such as those by Kassem *et al.* (2019), where behavioral monitoring systems contributed positively when tied to driver training and insurance incentives.

Similarly, communication systems did not show a statistically significant effect ($\beta = 0.084$, $p = 0.494$), despite their high correlation with other predictors. This insignificance could be due to overlapping functions with infrastructure and vehicle assistance technologies, leading to multicollinearity. Alternatively, the communication systems in use might be underdeveloped or poorly integrated into enforcement or emergency protocols in the local context, reducing their direct impact. Studies by Wang *et al.* (2020) suggest that communication technologies are most effective when tightly integrated with responsive traffic control and emergency systems—something that may still be evolving in Nairobi.

In summary, while all the IoT-based technologies showed strong conceptual linkages to road safety, the regression results indicate that road infrastructure and vehicle assistance technologies are currently the most effective predictors of road safety performance in Nairobi. These results suggest that policy and investment efforts should prioritize infrastructure and vehicle-level technologies to achieve significant improvements in safety outcomes, while continuing to develop and integrate behavioral and communication systems for long-term impact.

5.0 Conclusions of the Study

The study concludes that road safety management in Nairobi County is significantly influenced by various Internet-of-Things (IoT) technologies. Specifically, the research found that road infrastructure technologies, such as smart traffic signals and automated speed enforcement systems, have the strongest impact on improving road safety. The study confirms that these technologies play a key role in ensuring safer driving conditions, smoother traffic flow, and enhanced policy compliance. The high mean ratings and strong statistical significance suggest that road infrastructure is the most critical IoT-based intervention for road safety in Nairobi.

In addition, the study concludes that driver behavior monitoring systems, while not as strongly correlated with road safety management as road infrastructure technologies, still play an important role. The use of monitoring tools like in-vehicle cameras and GPS-based tracking is seen as a valuable approach to addressing driver behavior issues such as speeding and fatigue. Although the regression analysis did not find a statistically significant direct effect of these systems on road safety, the correlation analysis strongly suggests their perceived importance. This indicates that, while their direct impact may be smaller compared to other variables, they remain an integral part of the safety management framework.

The research also concludes that communication systems, although perceived positively by respondents, do not show a statistically significant effect on road safety management when accounting for other IoT technologies. While technologies like vehicle-to-vehicle communication and real-time alerts are valued for enhancing emergency responses and coordination, they appear less central to improving road safety compared to other variables like infrastructure or vehicle assistance technologies. The relatively weak regression results imply that these communication systems may serve more as a complementary feature rather than a primary driver of road safety outcomes.

Furthermore, the study concludes that vehicle assistance technologies, such as smart braking systems and automated lane-keeping assistance, significantly contribute to road safety in Nairobi County. These systems were shown to have a statistically significant impact, confirming their effectiveness in reducing accidents and supporting drivers in real-time decision-making. Their positive correlation with road safety management, along with their significant regression coefficient, underscores their importance in enhancing driver safety and reducing human error.

6.0 Recommendations from the Study

The study recommends that Nairobi County Government prioritize the integration of Internet-of-Things (IoT) technologies in its road safety management strategies. Given the significant positive impact of road infrastructure technologies, such as smart traffic signals and automated speed enforcement systems, the county should focus on expanding these technologies across key traffic hotspots. This helped streamline traffic flow, reduce congestion, and mitigate the risk of accidents. Investing in the development and maintenance of smart infrastructure, including adaptive traffic light systems and automatic road condition monitoring, can significantly improve road safety outcomes. Additionally, partnerships with technology providers to offer cost-effective solutions for these technologies would be essential for expanding their reach within the county.

The study also recommends that the county invest in driver behavior monitoring systems. While not as directly influential as road infrastructure, driver behavior monitoring through GPS tracking and real-time feedback systems could significantly reduce risky behaviors like speeding, distracted driving, and fatigue. A targeted policy should be developed to incorporate these technologies into public and private transportation fleets, with incentives for compliance. Regular training on safe driving behaviors should be coupled with these technologies, ensuring that drivers understand their role in improving road safety. Such programs should be backed by continuous monitoring to assess their effectiveness and adjust interventions where necessary.

Communication systems, though crucial for real-time information sharing, were found to have a more supplementary role in the broader context of road safety management. The study recommends that Nairobi County Government explore the further development of vehicle-to-vehicle (V2V) communication networks and real-time emergency alerts. These technologies can be incorporated into existing road safety systems to improve communication during accidents or traffic disturbances, ensuring faster response times. However, since the study did not find a direct significant impact of communication systems on road safety outcomes, these systems should be implemented alongside more effective interventions, such as infrastructure enhancements and vehicle assistance technologies. The focus should be on complementing existing technologies to strengthen their impact on road safety.

Vehicle assistance technologies, such as automated braking and lane-keeping systems, showed a statistically significant impact on reducing accidents and improving safety. The study recommends the adoption of these systems within both public transport and private vehicles. Nairobi County should work with automobile manufacturers and fleet operators to ensure that vehicle assistance technologies are adopted on a larger scale. Additionally, public awareness campaigns should be launched to educate drivers on the benefits of these technologies. As these systems play a key role in reducing human error, investing in their adoption could lead to long-term reductions in traffic accidents and fatalities.

Lastly, the study recommends that Nairobi County Government take a multi-faceted approach to integrate these IoT technologies into the broader road safety policy. A comprehensive roadmap should be developed, integrating the various technologies discussed (road infrastructure, driver behavior monitoring, communication systems, and vehicle assistance) into a cohesive plan that tackles multiple facets of road safety. Collaboration with other counties, research institutions, and technology companies would be vital in ensuring that the county stays at the forefront of technological advancements in road safety. Moreover, continuous monitoring and evaluation should be conducted to assess the effectiveness of the implemented technologies, with an emphasis on data-driven adjustments to improve road safety continuously.

These recommendations aim to create a safer, more efficient road environment in Nairobi County, leveraging the full potential of IoT technologies to address pressing road safety challenges. The integration of these technologies would not only improve public safety but also foster a culture of innovation and technological adoption in Kenya's transport sector.

REFERENCES

Abebe, T., & Mekonnen, H. (2019). IoT-enabled pedestrian safety applications in Addis Ababa. African Journal of Traffic Studies, 9(2), 45-60.

Adewale, T., & Balogun, A. (2021). Mobile road safety applications in Lagos: A technology-driven approach. African Journal of Smart Mobility, 15(1), 112-128.

Adeyemi, K., Omisakin, T., & Ogunleye, A. (2020). GPS systems and road safety management among public buses in Lagos. African Journal of Transport Safety, 9(2), 45-60.

Akinyi, R., Mutisya, M., & Mwangi, W. (2021). Comparative analysis of road traffic accident rates in East Africa: Trends and policy implications. *Journal of East African Studies*, 15(3), 367-384.

Andersson, L. (2021). Vision Zero and the role of IoT technologies in achieving zero traffic fatalities. *Transport Policy*, 99, 54-62.

Becvar, R. J., Becvar, D. S., & Reif, L. V. (2023). Systems theory and family therapy: A primer. Rowman & Littlefield.

Bhattacharya, S., Jha, H., & Nanda, R. P. (2022). Application of iot and artificial intelligence in road safety. 2022 Interdisciplinary Research in Technology and Management (IRTM), 1-6. https://doi.org/10.1109/IRTM54583.2022.9791563

Call, D. R., & Herber, D. R. (2022). Applicability of the diffusion of innovation theory to accelerate model-based systems engineering adoption. Systems Engineering, 25(6), 574-583.

Chen, X., Liu, Z., & Wang, L. (2020). Proximity sensors and urban collision prevention in Shanghai. Asian Journal of Smart Transportation, 9(4), 210-225.

Chen, Z., & Wang, L. (2019). Wearable IoT devices for fatigue detection in commercial driving. International Journal of Smart Systems, 29(6), 567-583.

European Union, (2023). EU Strategic Action Plan on Road Safety. Department of Transportation Planning and Engineering, National Technical University of Athens

Fantin Irudaya Raj, E., & Appadurai, M. (2022). Internet of things-based smart transportation system for smart cities. In Intelligent Systems for Social Good: Theory and Practice (pp. 39-50). Singapore: Springer Nature Singapore.

Gatera, A. (2022). Towards improved road traffic safety: A modelling and IoT integration approach (Doctoral dissertation, University of Rwanda (College of science and Technology)).

Goh, E., & Sigala, M. (2020). Integrating Information & Communication Technologies (ICT) into classroom instruction: teaching tips for hospitality educators from a diffusion of innovation approach. *Journal of teaching in travel & tourism*, 20(2), 156-165.

Guest, D., Knox, A., & Warhurst, C. (2022). Humanizing work in the digital age: Lessons from socio-technical systems and quality of working life initiatives. Human relations, 75(8), 1461-1482.

Harrison, P., & Smith, T. (2018). Lane assist systems and highway safety in Germany. European Journal of Transport Technologies, 16(3), 140-156.

Hernandez, M., Lopez, D., & Garcia, R. (2018). Smart traffic signal systems and urban road safety: A case study in Barcelona. European Journal of Transport Safety, 15(3), 89-104.

Jones, A., & Cooper, D. (2019). V2X communication and urban traffic safety in the UK. European Journal of Transportation Studies, 22(4), 67-81.

Kamau, P., & Wanjiru, S. (2023). Urbanization and traffic congestion: A case study of Nairobi County. *African Urban Studies*, 8(2), 145-159.

Kariuki, J., Mwangi, C., & Ndungu, P. (2022). Pedestrian safety systems and accident prevention in Nairobi. Kenyan Journal of Road Technologies, 14(1), 56-72.

Katebi, A., Homami, P., & Najmeddin, M. (2022). Acceptance model of precast concrete components in building construction based on Technology Acceptance Model (TAM) and Technology, Organization, and Environment (TOE) framework. Journal of Building Engineering, 45, 103518.

Kibue, G. (2021). Evaluating the effectiveness of road safety campaigns in Kenya: An assessment of public awareness and behavioral change. *Kenya Journal of Public Health*, 12(4), 112-127.

Kimani, P., Wairimu, S., & Kariuki, E. (2022). The role of V2V systems in matatu safety in Nairobi. Kenyan Journal of Road Safety, 12(1), 110-125.

KNBS. (2023). *Annual report on road traffic accidents in Kenya*. Kenya National Bureau of Statistics.

Kobayashi, S., Tanaka, M., & Yamamoto, T. (2020). Automated collision avoidance systems and highway safety in Japan. Asian Journal of Road Safety, 11(3), 200-214.

Kobayashi, T., Tanaka, Y., & Yamamoto, K. (2023). Advanced driver assistance systems (ADAS) and automated driving technologies in Japan: Enhancements in road safety. *International Journal of Automotive Technology*, 24(1), 29-41.

Kumar, R., Banga, H. K., & Kaur, H. (2020, November). Internet of Things-supported smart city platform. In IOP Conference Series: Materials Science and Engineering (Vol. 955, No. 1, p. 012003). IOP Publishing.

Kumar, S., Tiwari, P., & Zymbler, M. (2019). Internet of Things is a revolutionary approach for future technology enhancement: a review. Journal of Big data, 6(1), 1-21.

Lee, H., & Park, J. (2017). The influence of V2V communication on highway safety in South Korea. International Journal of Smart Mobility, 14(3), 120-136.

Lee, J., Patel, R., & Zhang, L. (2023). IoT-based traffic management systems in Austin, Texas: Optimizing traffic signal timings. *Journal of Urban Traffic Management*, 21(1), 88-101.

Matsuda, Y., & Kato, S. (2020). IoT-based roadway lighting and nighttime accident prevention in Tokyo. Journal of Smart Infrastructure, 8(4), 267-283.

Mbugua, C., & Ndegwa, J. (2023). Potential applications of Internet of Things (IoT) technologies in Nairobi County: Opportunities and challenges. *Journal of African Technology and Innovation*, 11(2), 134-147.

Miller, H. (2022). Systems Theory and real-time data: Implications for road safety improvements. *Journal of Safety Research*, 83, 45-58.

Moyo, T., & Banda, C. (2021). IoT-enabled driver coaching systems: A South African perspective. Journal of African Smart Technologies, 7(1), 56-72.

Mulaa, L. A. (2023). Determinants of Performance of Road Safety Programs Implemented by the National Transport and Safety Authority (NTSA), Nairobi County, Kenya (Doctoral dissertation, University of Nairobi).

Munyao, M. N. (2022). The Effect of partnership collaboration on road safety: a case of the National Transport and Safety Authority and the Kenya Police at the Coastal Region of Kenya (Doctoral dissertation, Strathmore University).

Mutale, P., & Zulu, J. (2021). V2I communication and road safety improvements in Lusaka. Journal of African Smart Transportation, 8(3), 90-105.

Muthoni, G. (2022). Traffic accident patterns and infrastructure challenges in Nairobi. *Nairobi Metropolitan Review*, 17(3), 202-214.

Mwangi, K., Ndungu, J., & Wanjiru, P. (2022). Lane assist technologies and urban safety in Nairobi. Kenyan Journal of Transportation Safety, 14(3), 67-82.

Mwangi, K., Wambugu, S., & Njoroge, J. (2022). Adoption of GPS-based systems among taxi operators in Nairobi. Kenyan Journal of Road Safety, 11(2), 145-160.

Na, S., Heo, S., Han, S., Shin, Y., & Roh, Y. (2022). Acceptance model of artificial intelligence (AI)-based technologies in construction firms: Applying the Technology Acceptance Model (TAM) in combination with the Technology–Organisation–Environment (TOE) framework. Buildings, 12(2), 90.

Natasia, S. R., Wiranti, Y. T., & Parastika, A. (2022). Acceptance analysis of NUADU as e-learning platform using the Technology Acceptance Model (TAM) approach. Procedia Computer Science, 197, 512-520.

Ndlovu, T., & Dube, S. (2021). Vehicle assistance technologies and public bus safety in Harare. Journal of African Smart Mobility, 11(2), 95-110.

Ngoma, P., & Chanda, J. (2019). Road safety awareness campaigns and accident reduction in Lusaka. Journal of African Transportation Studies, 10(2), 67-80.

Ngugi, S., Karanja, L., & Kimani, D. (2022). Awareness and impact of road safety campaigns among Nairobi drivers. *Kenya Traffic Safety Journal*, 14(2), 98-115.

Nkosi, B., Mkhize, P., & Zuma, L. (2021). Smart traffic systems and road safety in Johannesburg. Journal of African Urban Studies, 12(3), 101-117.

NTSA, (2024). About Us. Accessed from https://ntsa.go.ke/

NTSA. (2023). *Road traffic accident statistics 2022*. National Transport and Safety Authority.

Ochieng, D. (2022). Factors contributing to traffic accidents in Kenya: A review of recent trends. *Kenyan Journal of Transport Studies*, 19(1), 55-70.

Ochieng, P., Njoroge, M., & Wanjiru, L. (2022). Pedestrian infrastructure improvements and road safety in Nairobi. Kenyan Journal of Transport Safety, 17(2), 89-104.

Odera, N., & Karanja, J. (2023). IoT technologies and road safety: A review of international practices and their applicability in Kenya. *Technology and Innovation Journal*, 16(1), 90-105.

Okonkwo, A., Eze, C., & Udeh, P. (2020). The role of telematics in monitoring commercial drivers in Nigeria. African Journal of Transportation, 12(4), 78-95.

Okoro, A., & Nwosu, C. (2019). Automatic braking systems and taxi safety in Abuja. African Journal of Road Technologies, 8(1), 75-90.

Omollo, G., Muturi, T., & Akinyi, E. (2024). The impact of fatigue detection systems on truck drivers in Kenya. East African Transport Review, 16(1), 34-49.

Omollo, L. J. (2016). Applicability of Internet of Things (Iot) to Reduce Traffic Congestion in Nairobi City, Kenya (Doctoral dissertation, University of Nairobi).

Otieno, L., & Kamau, E. (2023). Automatic braking systems in Kisumu's public transport sector. East African Journal of Traffic Safety, 19(1), 145-160.

Otieno, T., & Achieng, R. (2023). GPS navigation and safety among boda boda operators in Kisumu. East African Journal of Transportation Research, 19(2), 140-155.

Smith, J., Brown, T., & Johnson, R. (2017). The impact of telematics on driver behavior and road safety: A longitudinal study. Journal of Transport Safety, 45(3), 123-140.

Smith, R. (2022). Enhancing road safety with IoT-enabled cameras and sensors. *Journal of Transportation Safety*, 28(4), 124-135.

Smith, R., & Lee, J. (2021). The role of IoT technologies in improving road safety: Case studies and global insights. *International Journal of Traffic Management*, 32(2), 115-130.

Sony, M., & Naik, S. (2020). Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model. Technology in society, 61, 101248.

Tan, J. (2023). Implementing smart traffic lights in Singapore: A case study on improving road safety. *Asian Transport Journal*, 19(2), 75-89.

Thakur, A., & Malekian, R. (2019). Internet of vehicles communication technologies for traffic management and road safety applications. Wireless Personal Communications, 109(1), 31-49. https://doi.org/10.1007/s11277-019-06548-y

Torbaghan, M. E., Sasidharan, M., Reardon, L., & Muchanga-Hvelplund, L. C. (2022). Understanding the potential of emerging digital technologies for improving road safety. Accident Analysis & Prevention, 166, 106543.

Wagner, R. E. (2020). Macroeconomics as systems theory. Springer International Publishing. https://doi.org/10.1007/978-3-030-44465-5

Wanjala, E., & Otieno, L. (2023). Adaptive traffic lights and intersection safety in Nairobi. East African Journal of Transportation Research, 19(2), 134-149.

Wanjiru, E., & Kimani, J. (2023). Speed cameras and accident reduction on Kenyan highways. East African Journal of Traffic Studies, 21(1), 145-160.

Wanjiru, M. M. (2021). Influence of Electronic Service Strategy on Service Delivery of National Transport and Safety Authority of Kenya (Doctoral dissertation, University of Nairobi).

Williams, D., & Carter, R. (2017). The impact of congestion management strategies on road safety in New York City. Journal of Urban Traffic Studies, 13(4), 102-118.

Williams, J. (2021). Safety Management Systems and their relevance to modern road safety practices. *Safety Science Review*, 22(1), 18-30.

Zhao, L. (2020). Predicting and preventing traffic accidents using IoT technologies. *Journal of Intelligent Transportation Systems*, 24(3), 196-210.