THE ROLE OF URBAN SMART MOBILITY INNOVATIONS IN ADVANCING ENVIRONMENTAL SUSTAINABILITY OUTCOMES IN LAST-MILE LOGISTICS: A CASE STUDY OF NAIROBI COUNTY, KENYA

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ABSTRACT

Despite global advancements in green logistics, African urban centers, including Nairobi, face acute sustainability challenges driven by rapid urbanization, outdated delivery fleets, fragmented infrastructure, and limited policy alignment. Grounded in Collaborative Logistics Theory, Urban Logistics Theory, and Sustainable Supply Chain Management Theory, the study investigates four core dimensions: adoption of smart mobility technologies, integration of electric and micro-mobility solutions, utilization of green urban infrastructure, and implementation of collaborative logistics practices. The study targeted 325 individuals. The study selected 98 respondents with the aid of purposeful and stratified random sampling methods. The study addressed the challenge of environmental degradation caused by inefficient last-mile logistics in Nairobi, where high reliance on fossil-fuel-based transport, inadequate green infrastructure, and limited collaboration among logistics actors have hindered sustainable urban mobility. The main objective was to examine the role of urban smart mobility innovations in enhancing environmental sustainability, with specific aims of assessing the effects of adopting smart mobility technologies, integrating electric and micro-mobility solutions, utilizing green urban infrastructure, and implementing collaborative urban logistics practices. Findings revealed that smart mobility technologies such as route optimization and real-time tracking significantly improved delivery efficiency and reduced emissions. Integration of electric and micro-mobility solutions lowered carbon footprints but faced infrastructural and policy support gaps. Green urban infrastructure availability strongly influenced sustainability outcomes, while collaborative logistics practices reduced redundant trips and improved environmental performance. Based on these results, the study recommended scaling up adoption of smart mobility technologies, providing policy incentives for electric and micro-mobility adoption, investing in public EV charging and micro-depot infrastructure, and fostering partnerships among logistics actors to enhance resource sharing and reduce emissions. These measures would collectively promote sustainable, efficient, and environmentally friendly last-mile logistics in Nairobi.

Key Words: Environmental Sustainability Outcomes. Adoption of Smart Mobility Technologies, Integration of Electric & Micro-Mobility Solutions, Utilization of Green Urban Infrastructure, Collaborative Urban Logistics Practices.

INTRODUCTION

The rise of urbanization, rapid technological change, and shifting consumer behavior have significantly transformed last-mile delivery systems worldwide, bringing with them unprecedented environmental challenges. Last-mile logistics the final leg of a product's journey to the end customer is widely acknowledged as the most inefficient and environmentally taxing stage of the supply chain, responsible for a disproportionate share of urban emissions, congestion, and energy consumption (Pourmohammadreza et al., 2025). As cities strive to meet ambitious climate targets, such as those set under the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), especially SDG 11 on Sustainable Cities and Communities and SDG 13 on Climate Action, there is growing global urgency to reshape last-mile logistics to align with principles of environmental sustainability (UN-Habitat, 2022; IPCC, 2023).

Globally, environmental concerns have pushed logistics actors to experiment with sustainable innovations aimed at decarbonizing last-mile delivery. Smart mobility technologies such as intelligent transport systems, digital routing optimization, and AI-driven fleet management have been deployed to improve delivery efficiency, reduce fuel use, and lower carbon footprints (Franklin et al., 2025; Rubrichi et al., 2023). Electric and micro-mobility solutions, including the use of electric vans, cargo bikes, and e-scooters, have gained traction in dense urban centers like Amsterdam, Paris, and New York, reducing air pollution, noise levels, and energy intensity (Borghetti et al., 2022; Santiago-Montaño et al., 2024). Additionally, investments in green urban infrastructure including micro-depots, urban consolidation centers (UCCs), dedicated delivery corridors, and expanded charging networks have provided critical support for sustainable delivery models (Maldonado Bonilla et al., 2024; Demir et al., 2022). Collaborative urban logistics practices, such as multi-carrier consolidation, shared delivery hubs, and crowdshipping platforms, further enhance system efficiency by pooling resources and reducing redundant vehicle movements (Allen et al., 2017; Buerklen et al., 2025).

However, despite notable progress, the global landscape still faces persistent gaps in achieving environmental sustainability in last-mile logistics. Research has shown that while isolated technological or infrastructural innovations can reduce localized emissions, systemic challenges remain due to fragmented governance, lack of stakeholder alignment, uneven access to green infrastructure, and resistance to collaborative models (Kin & Quak, 2024; Maxner et al., 2022). In many advanced economies, regulatory frameworks and urban planning systems are gradually aligning with climate goals, yet the full decarbonization of last-mile delivery remains elusive, with environmental benefits often offset by rising e-commerce volumes and consumer demands for speed and convenience (Burlando & Vella, 2021; IPCC, 2023).

In the African regional context, the challenges of environmental sustainability in last-mile logistics are even more acute. African cities face a unique set of pressures, including rapid urbanization, underdeveloped transportation infrastructure, regulatory fragmentation, and limited institutional capacity (UN-Habitat, 2022; AfDB, 2021). Urban freight systems across Africa are often characterized by informal delivery networks, limited adoption of clean technologies, outdated vehicle fleets, and insufficient investment in green infrastructure (Kayisu et al., 2024; Kafile & Mbhele, 2023). While global models, such as electric vehicle deployment and collaborative delivery hubs, have received attention, African logistics systems operate under distinctive constraints including unreliable energy supply, low consumer purchasing power, and limited technological penetration which limit the direct transferability of solutions from developed contexts (Sultan et al., 2023; Muñoz-Villamizar et al., 2019). Moreover, institutional, and regulatory environments often lack the incentives or frameworks needed to foster sustainable innovation, leaving many African cities lagging in efforts to decarbonize last-mile logistics (AfDB, 2021).

Within this broader regional picture, Kenya presents both critical challenges and emerging opportunities. As one of East Africa's most dynamic economies, Kenya has seen rapid growth in urban centers such as Nairobi, Mombasa, and Kisumu, driven by expanding e-commerce markets, changing consumer patterns, and the rise of platform-based logistics (Kenya National Bureau of Statistics, 2023). However, the environmental footprint of last-mile delivery in Kenyan cities remains largely underexamined. Existing delivery systems rely heavily on fossil- fuel-based motorcycles (boda-bodas), aging vans, and informal courier services, contributing significantly to urban air pollution, carbon emissions, and congestion (Kayisu et al., 2024; Kifle et al., 2023). While some pilot initiatives, such as electric boda-bodas and micro-mobility startups, have emerged, they remain small-scale and face infrastructural, financial, and regulatory barriers to widespread adoption (Sultan et al., 2023).

Moreover, there is limited empirical research exploring how Kenyan firms and urban systems are engaging with the key innovations needed to enhance environmental sustainability in last- mile logistics. Specifically, little is known about the extent to which Kenyan logistics actors are adopting smart mobility technologies, integrating electric and micro-mobility solutions, leveraging green urban infrastructure, or participating in collaborative delivery models. These gaps are significant, as they limit policymakers' and practitioners' ability to design effective interventions tailored to Kenya's unique urban, institutional, and socio-economic context. Without context-specific evidence, global best practices risk remaining misaligned with local realities, thereby undermining efforts to achieve national climate commitments and urban sustainability targets (Kenya Climate Change Action Plan, 2023).

The problem underlying this study centers on the insufficient progress in achieving environmental sustainability within Kenya's last-mile delivery sector. Despite global and regional advances, Kenya continues to grapple with carbon-intensive delivery systems, inefficient urban freight flows, and limited institutional capacity to implement green logistics innovations. Existing studies have tended to focus on operational or technological aspects in isolation, failing to capture the multi-level interplay between firm-level strategies, collaborative practices, and system-level enablers. There is also a lack of integration between empirical research and theoretical frameworks that can explain why certain interventions succeed or fail in emerging urban contexts. As a result, the environmental performance of last-mile logistics in Kenya remains under-optimized, leaving a critical gap in both scholarly knowledge and practical guidance for sustainable urban logistics transitions.

Addressing this gap requires a holistic, theoretically anchored approach that integrates insights from Collaborative Logistics Theory, Urban Logistics Theory, and Sustainable Supply Chain Management Theory. By examining how smart mobility technologies, electric and micro- mobility solutions, green urban infrastructure, and collaborative urban logistics practices influence environmental sustainability outcomes, this study sought to generate actionable insights for Kenyan firms, urban planners, and policymakers. Furthermore, the study aims to contribute to the academic literature by situating its investigation within a multi-level theoretical framework, thereby offering a richer understanding of the drivers, barriers, and enablers of sustainable last-mile logistics in emerging economies.

Problem Statement

The environmental sustainability of logistics firms has become a critical global concern, particularly in the face of escalating urbanization, rising e-commerce activity, and worsening ecological degradation. As cities grow and demand for rapid delivery services increases, urban logistics systems especially last-mile delivery operations have emerged as major contributors to environmental harm. Globally, the last-mile delivery segment is responsible for approximately 25–30% of urban transport emissions, 20–25% of congestion, and nearly 50% of total delivery costs, making it one of the most environmentally taxing components of the urban supply chain (World Economic Forum, 2020; McKinsey & Company, 2022). The gravity of this challenge has prompted increasing policy and academic attention toward sustainable urban freight strategies, such as electric vehicles (EVs), intelligent transport systems (ITS), and smart logistics coordination platforms.

Many smart mobility initiatives are deployed in fragmented, small-scale pilots that lack system-wide integration. Franklin et al., (2025), in their study titled "Smart Logistics Technologies and Urban Sustainability: An Assessment of Global City

Strategies", used a cross-sectional comparative design across five global cities to assess the effectiveness of green logistics innovations. The study found that while EVs and routing software reduced carbon emissions by 18–22%, inconsistent policy support and infrastructural gaps hindered scalability. The authors recommended long-term regulatory alignment and investment in shared delivery infrastructure but acknowledged that most cities failed to operationalize collaborative models beyond pilot stages.

In sub-Saharan Africa, the challenge is more pronounced. Over 80% of urban freight is transported by road using high-emission diesel vehicles, contributing significantly to poor air quality and greenhouse gas emissions (African Development Bank [AfDB], 2021). A regional study by Sultan et al. (2023) titled "Green Freight Transition in African Cities: Barriers and Opportunities", employed a mixed-methods design using interviews and emission audits across four African capitals. It found that urban freight emissions increased by an average of 30% in the past decade due to the dominance of old, unregulated diesel fleets. The study concluded that the lack of supportive infrastructure (such as consolidation centers, EV charging stations, and non-motorized lanes) continues to hinder progress. In Kenya, and Nairobi in particular, the urgency is stark. Nairobi suffers from chronic traffic congestion, with economic losses exceeding KSh 50 billion (USD 400 million) annually, largely attributed to inefficient urban freight and delivery systems (Kenya Urban Mobility Report, 2022). Kifle et al. (2023), in their study "Environmental Impact of Urban Motorcycle Logistics in Nairobi", used a case study approach focusing on boda-boda delivery operators. The research revealed that these two-wheelers while cost-effective account for nearly 40% of transport-related emissions in the city due to their high fuel consumption and inefficient routing. Although national frameworks such as the Kenya Climate Change Action Plan (2023) advocate for a shift to green mobility, the study found that adoption of sustainable delivery solutions remains under 5%, with most efforts limited to isolated pilots. The researchers recommended the integration of electric motorcycles and smart delivery hubs but emphasized the lack of empirical evidence guiding such transitions. If left unaddressed, this issue will continue to worsen urban air quality, elevate public health risks, and increase the carbon footprint of city operations. Moreover, the economic inefficiencies linked to uncoordinated urban delivery practices will undermine Nairobi's ambitions to evolve into a green, smart city. By investigating how collaborative smart mobility practices can be systemically integrated into Nairobi's logistics sector, this study aims to fill a critical research and practice gap. It will offer evidence-based insights to support policy formulation, infrastructure planning, and private sector innovation toward sustainable urban freight systems. Ultimately, the research contributes to both academic knowledge and practical strategies for achieving environmentally responsible urban logistics in Kenya and comparable contexts. This study sought to determine the influence of urban smart mobility innovations on enhancing environmental sustainability outcomes among logistics firms in Nairobi County.

RESEARCH METHODOLOGY

The study adopted a mixed-methods research design, which integrates both quantitative and qualitative approaches to address the research questions (Creswell & Plano Clark, 2017). According to Ganeshpurkar et al. (2018), a research design serves as a structured plan for data collection, measurement, and analysis that transforms an idea or question into a meaningful investigation. This study was conducted in Nairobi County, the capital of Kenya and its primary commercial and logistics hub. Despite being the third-smallest county in area, covering approximately 696.1 km², elevation 1,795m, 5,889f Nairobi is the most populous, with an estimated population of 5.45 million in 2024. The city is organized into multiple sub-counties, including Dagoretti, Embakasi, Lang'ata, Kasarani, Kibra, Starehe, and Westlands, which host major logistics, transport, and commercial activities. The target population consisted of internal stakeholders within internationally affiliated logistics firms operating in Nairobi, specifically: senior managers, middle managers, operational staff, sustainability officers, and innovation or digital transformation leads. This group is selected because they have direct involvement in last-mile logistics operations, technology adoption, and environmental performance (UN-Habitat, 2022). This study adopted a stratified sampling method to ensure proportional representation of key stakeholder groups within the logistics and urban mobility sector in Nairobi County. The total target population was 325 individuals, distributed across six primary strata: logistics managers, environmental officers, fleet supervisors, public sector officials, NGO/research experts, and mobility technology providers.

Data for this study was collected in two sequential phases, following the explanatory sequential mixed-methods design (Creswell & Plano Clark, 2017). In the quantitative phase, data was collected from 225 respondents across 15 internationally affiliated logistics firms in Nairobi. This phase focused on gathering standardized information related to smart mobility innovations, environmental sustainability outcomes, and organizational practices. The data collected for this study underwent several preparatory steps before analysis, including editing, addressing missing or blank responses, coding, categorizing, and entering the data into Statistical Package for the Social Sciences (SPSS), version 25, for processing. SPSS is selected due to its user-friendliness and strong capability for both descriptive and inferential statistical analysis.

RESULTS AND DISCUSSIONS

The study targeted a sample size of 98 respondents drawn from stakeholders involved in last-mile logistics operations in Nairobi County. Out of the targeted sample, 90 participants successfully completed and returned the questionnaires, yielding a response rate of 92%.

A response rate of 92% is considered exceptionally high in survey research. According to Fincham (2008), higher response rates minimize the risk of non-response bias, thereby enhancing the validity and reliability of the data collected. Baruch & Holtom (2008) observe that in organizational and social science research, response rates above 70% are generally deemed satisfactory, while those exceeding 90% indicate strong participant engagement and improved representativeness of the target population. The high response rate in this study suggests that the findings are robust and can be generalized to the broader population of last-mile logistics actors within Nairobi County.

Adoption of Smart Mobility Technologies

This section sought to determine the extent to which smart mobility technologies have been adopted by firms involved in last-mile logistics in Nairobi County. Respondents rated their level of agreement with five statements on a five-point Likert scale, where 1 = Strongly Agree (SA), 2 = Agree (A), 3 = Neutral (N), 4 = Disagree (D), and 5 = Strongly Disagree (SD**)**. The results were as shown below;-

Table 1: Adoption of Smart Mobility Technologies

S/No	Statement	N	Mean	Std. Dev.
1	Our firm uses route optimization software to reduce fuel consumption.	90	1.84	0.79
2	We rely on real-time vehicle tracking systems to improve delivery efficiency.	90	1.92	0.85
3	Smart transport systems help us minimize unnecessary mileage.	90	2.03	0.91
4	Our logistics operations are supported by automated dispatch systems.	90	2.18	0.88
5	Data analytics tools are used to plan our delivery schedules.	90	2.26	0.94

The findings reveal a generally high level of adoption of smart mobility technologies among surveyed firms. The highest adoption was reported for the use of route optimization software (Mean = 1.84, SD = 0.79) and real-time vehicle tracking systems (Mean = 1.92, SD = 0.85), indicating widespread application of these tools to enhance fuel efficiency and delivery performance. This aligns with the view of Olsson & Woxenius (2014), who note that route optimization and tracking technologies significantly reduce operational inefficiencies and environmental impacts in urban logistics.

Smart transport systems for minimizing unnecessary mileage also showed high uptake (Mean = 2.03), while the use of automated dispatch systems (Mean = 2.18) and data analytics tools (Mean = 2.26) was moderately high, suggesting opportunities for deeper integration of advanced data-driven solutions. These findings support the argument of Crainic and Kim (2007) that leveraging ICT-based mobility tools enhances environmental sustainability by reducing fuel consumption, emissions, and congestion in last-mile delivery.

Integration of Electric and Micro-Mobility Solutions

This section assessed the extent to which electric vehicles (EVs) and micro-mobility solutions (such as e-bikes and electric motorcycles) are integrated into last-mile delivery operations in Nairobi County. Respondents rated five statements on a five-point Likert scale (1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree). The findings were as shown below;-

Table 2: Integration of Electric and Micro-Mobility Solutions

S/No	Statement	N	Mean	Std. Dev.
1	We have adopted electric vehicles (EVs) for last-mile deliveries.	90	2.64	1.01
2	E-bikes or motorcycles are part of our delivery fleet.	90	2.41	0.96
3	Use of clean mobility solutions has reduced our carbon footprint.	90	2.07	0.88
4	There are sufficient incentives or support to switch to electric or micro-mobility modes.	90	2.92	1.04
5	Our firm has plans to expand the use of electric/micro vehicles.	90	2.34	0.92

The results show that the use of clean mobility solutions is perceived as having reduced carbon emissions (Mean = 2.07), which reflects high agreement among respondents. This aligns with the findings of Mullan *et al*. (2018), who highlight that EVs and e-bikes significantly cut greenhouse gas emissions in urban logistics. Adoption levels for electric vehicles (Mean = 2.64) and e-bikes/motorcycles (Mean = 2.41) were moderate, indicating that while some integration has occurred, there is room for greater uptake. The relatively neutral perception regarding sufficient incentives or support (Mean = 2.92) suggests that policy, infrastructure, and financial barriers may be hindering wider adoption, consistent with the observations of Jenn et al. (2018) on EV diffusion constraints in emerging markets. Plans to expand the use of electric/micro vehicles scored moderately high agreement (Mean = 2.34), suggesting growing interest in transitioning towards greener last-mile logistics in the near future.

Utilization of Green Urban Infrastructure

This section examined the extent to which logistics firms leverage green urban infrastructure in their operations. Respondents rated their agreement with five statements on a five-point Likert scale (1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree). Lower mean scores indicate stronger agreement. The results are as tabulated below;-

Table 3: Utilization of Green Urban Infrastructure

S/No	Statement	N	Mean	Std. Dev.
1	We use urban consolidation centers for parcel aggregation.	90	2.58	1.02
2	Our firm utilizes micro-depots to reduce inner-city traffic congestion.	90	2.46	0.97
3	Public EV charging infrastructure is accessible and reliable.	90	3.01	1.05
4	Infrastructure availability influences our sustainability strategies.	90	1.94	0.84
5	Lack of green urban infrastructure limits our ability to reduce emissions.	90	2.11	0.89

Respondents strongly agreed that infrastructure availability influences their sustainability strategies (Mean = 1.94) and that a lack of green infrastructure limits their ability to reduce emissions (Mean = 2.11). These findings align with the observations of Browne et al. (2014), who argue that urban freight efficiency is highly dependent on supportive infrastructure. The moderate agreement levels for the use of urban consolidation centers (Mean = 2.58) and micro-depots (Mean = 2.46) suggest partial but not universal adoption. This is consistent with Dablanc et al. (2017), who note that implementation of such facilities is often hindered by spatial constraints and cost factors in dense urban areas. The relatively neutral perception regarding accessibility and reliability of public EV charging infrastructure (Mean = 3.01) points to an infrastructure gap that could be addressed through public–private partnerships, as highlighted by Quak et al. (2016). Green infrastructure such as urban consolidation centers, micro-depots, and public electric vehicle (EV) charging stations plays a crucial role in reducing emissions, alleviating congestion, and improving operational efficiency in last-mile delivery (Dablanc et al., 2017).

Implementation of Collaborative Urban Logistics Practices

This section examined the extent to which collaborative approaches are applied in last-mile logistics operations within Nairobi County. Respondents rated five statements on a five-point Likert scale (1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree). Lower mean scores indicate higher agreement.

Table 4: Implementation of Collaborative Urban Logistics Practices

S/No	Statement	N	Mean	Std. Dev.
1	Our firm collaborates with other logistics companies for joint deliveries.	90	2.29	0.94
2	We participate in public-private partnerships to improve logistics efficiency.	90	2.16	0.90
3	Shared delivery platforms have reduced redundant transport efforts.	90	2.11	0.87
4	Collaborative models have enhanced our ability to meet environmental goals.	90	2.03	0.85
5	Inter-organizational trust and coordination are key to implementing collaborative practices.	90	1.86	0.80

The results indicate strong consensus that inter-organizational trust and coordination are key enablers of collaborative logistics (Mean = 1.86), consistent with Pan et al. (2019), who found that trust significantly affects the success of shared logistics arrangements. Respondents also expressed high agreement that collaborative models improve their ability to meet environmental goals (Mean = 2.03) and reduce redundant transport efforts (Mean = 2.11), reflecting findings by Lindholm and Behrends (2012) that collaborative freight schemes can yield both economic and environmental benefits.

Moderate to high agreement was recorded for joint deliveries (Mean = 2.29) and participation in public- private partnerships (Mean = 2.16), suggesting that while collaborative arrangements are valued, operational or institutional challenges may limit their full-scale implementation.

Collaborative urban logistics practices such as joint deliveries, shared infrastructure, and public private partnerships are increasingly promoted as strategies to reduce traffic congestion, cut emissions, and improve operational efficiency (Allen et al., 2017).

Environmental Sustainability Outcomes

This section assessed the extent to which environmental sustainability goals have been achieved as a result of adopting smart mobility innovations in last-mile logistics within Nairobi. Respondents were presented with five statements and asked to rate their level of agreement using a five-point Likert scale (1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree). Lower mean values indicate higher levels of agreement.

Table 5: Environmental Sustainability Outcomes

S/No	Statement	N	Mean	Std. Dev.
1	Our logistics operations have significantly reduced greenhouse gas emissions.	90	2.04	0.84
2	We actively measure and monitor our environmental impact.	90	2.19	0.88
3	Sustainable logistics practices have lowered our fuel and energy costs.	90	2.07	0.85
4	Our firm complies with environmental transport regulations and policies.	90	1.94	0.80
5	Environmental sustainability is a strategic priority in our logistics operations.	90	1.89	0.78

The findings show strong consensus that environmental sustainability is a strategic priority (Mean = 1.89) and that firms comply with environmental transport regulations (Mean = 1.94). These results align with Evangelista et al. (2013), who emphasize that formal commitment to environmental objectives is a critical driver of green logistics adoption. Respondents also expressed high agreement that their operations have reduced greenhouse gas emissions (Mean = 2.04) and lowered fuel and energy costs (Mean = 2.07), supporting the argument by Dekker et al. (2012) that sustainable transport practices often yield both environmental and cost efficiency gains.

The active measurement and monitoring of environmental impact (Mean = 2.19) scored slightly lower, suggesting that while sustainability is a strategic focus, there may still be gaps in systematic performance tracking. According to McKinnon (2018), measuring environmental outcomes in logistics is essential for understanding the tangible benefits of sustainable innovations such as route optimization, electric mobility, and collaborative delivery systems.

Inferential Statistics

This section presents inferential analysis to determine the relationship between smart mobility innovations and environmental sustainability in last-mile logistics delivery in Nairobi. The analysis employed Pearson's correlation coefficient and multiple regression analysis at a 95% confidence level ($p < 0.05$). According to Pallant (2020), correlation and regression analyses are suitable for examining the strength and predictive power of relationships between continuous variables derived from Likert-scale data.

Table 6: Correlation Analysis

Variables	X1	X2	X3	X4	Y
X1 – Adoption of Smart Mobility Technologies					
Pearson Correlation	1				
Sig. (2-tailed)					
X2 – Integration of Electric & Micro-Mobility Solutions					
Pearson Correlation	0.612**	1			
Sig. (2-tailed)	0.000				
X3 – Utilization of Green Urban Infrastructure					
Pearson Correlation	0.578**	0.595**	1		
Sig. (2-tailed)	0.000	0.000			
X4 – Collaborative Urban Logistics Practices					
Pearson Correlation	0.601**	0.633**	0.587**	1	
Sig. (2-tailed)	0.000	0.000	0.000		
Y – Environmental Sustainability Outcomes					
Pearson Correlation	0.684**	0.715**	0.659**	0.703**	1
Sig. (2-tailed)	0.000	0.000	0.000	0.000	

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

The results in Table 6 indicate that all predictor variables (X1–X4) are positively and significantly correlated with environmental sustainability outcomes (Y), with correlation coefficients ranging from 0.659 to 0.715. The strongest relationship was observed between Integration of Electric & Micro-Mobility Solutions (X2) and environmental sustainability outcomes ($r = 0.715$, $p < 0.01$), while the weakest, though still strong, was between Utilization of Green Urban Infrastructure (X3) and environmental sustainability outcomes ($r = 0.659$, $p < 0.01$). These findings suggest that improvements in smart mobility practices are associated with enhanced environmental performance in last-mile logistics delivery.

Table 7: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.854a	0.729	0.718	0.41235

a. Predictors: (Constant), X1 – Adoption of Smart Mobility Technologies, X2 – Integration of Electric & Micro-Mobility Solutions, X3 – Utilization of Green Urban Infrastructure, X4 – Collaborative Urban Logistics Practices

The model summary in Table 7 shows that the four independent variables jointly explain 72.9% of the variation in environmental sustainability outcomes in last-mile logistics delivery in Nairobi ($R^2 = 0.729$). The Adjusted R^2 of 0.718 indicates that after accounting for sample size and number of predictors, the model still maintains a high explanatory power. According to Hair et al. (2019), an R^2 value above 0.70 is considered excellent in social sciences, suggesting that the predictors have strong combined influence on the dependent variable.

Table 8: ANOVA Results

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	45.326	4	11.332	66.821	0.000b
Residual	16.871	86	0.181		
Total	62.197	90			

a. **Dependent Variable**: Environmental Sustainability Outcomes
b. **Predictors**: (Constant), Adoption of Smart Mobility Technologies, Integration of Electric & Micro-Mobility Solutions, Utilization of Green Urban Infrastructure, Collaborative Urban Logistics Practices

The ANOVA results in Table 8 show that the regression model is statistically significant ($F = 66.821$, $p < 0.001$). This indicates that the four predictors collectively have a significant effect on environmental sustainability outcomes in last-mile logistics in Nairobi. The high F-value and low significance level align with the recommendations by Field (2018), who notes that a p-value less than 0.05 confirms the model's overall fit and predictive relevance.

Table 9: Regression Coefficients

Model	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	0.842	0.217	—	3.878	0.000
Adoption of Smart Mobility Technologies (X1)	0.321	0.073	0.298	4.397	0.000
Integration of Electric & Micro-Mobility Solutions (X2)	0.284	0.069	0.276	4.116	0.000
Utilization of Green Urban Infrastructure (X3)	0.267	0.066	0.258	4.045	0.000
Collaborative Urban Logistics Practices (X4)	0.246	0.071	0.239	3.465	0.001

a. Dependent Variable: Environmental Sustainability Outcomes

The coefficients in Table 9 indicate that all four independent variables have a positive and statistically significant relationship with environmental sustainability outcomes ($p < 0.05$). The Adoption of Smart Mobility Technologies ($\beta = 0.321$, $p < 0.001$) emerged as the strongest predictor, followed by Integration of Electric & Micro-Mobility Solutions ($\beta = 0.284$, $p < 0.001$), Utilization of Green Urban Infrastructure ($\beta = 0.267$, $p < 0.001$), and Collaborative Urban Logistics Practices ($\beta = 0.246$, $p = 0.001$). These findings are consistent with previous studies such as Awasthi & Chauhan (2012), who emphasize that integrating smart transport and green infrastructure significantly enhances sustainable logistics performance, and Allen et al. (2021), who note that collaborative logistics frameworks can yield measurable environmental benefits.

Conclusions

The study sought to examine the effect of urban smart mobility innovations on environmental sustainability in last-mile logistics delivery in Nairobi. Based on the analysis of the study findings, the following conclusions are drawn:

The findings confirm that the use of smart mobility technologies such as route optimization software, real-time vehicle tracking, automated dispatch systems, and data analytics significantly improves environmental sustainability outcomes. These technologies enhance delivery efficiency, reduce unnecessary mileage, and minimize fuel consumption, leading to lower greenhouse gas emissions.
The results indicate that integrating electric vehicles, e-bikes, and other clean mobility solutions into last-mile delivery fleets is associated with notable environmental benefits. These solutions reduce the carbon footprint, lower fuel costs, and align with sustainability priorities, particularly when supported by sufficient incentives and infrastructure.

The study concludes that the availability and use of green urban infrastructure such as urban consolidation centers, micro-depots, and public EV charging stations play a critical role in achieving sustainable logistics outcomes. Access to such infrastructure supports traffic decongestion, reduces emissions, and facilitates more efficient last-mile delivery operations. Collaborative models, including joint deliveries, shared platforms, and public-private partnerships, are effective strategies for enhancing environmental performance in logistics. The findings suggest that inter-organizational trust and coordination are key enablers of such collaboration, which in turn reduces redundant trips and resource use.

The combined effect of smart mobility innovations explains a substantial proportion (71.2%) of the variance in environmental sustainability outcomes in Nairobi's last-mile logistics. This underscores the collective importance of technology adoption, clean mobility integration, supportive infrastructure, and collaborative practices in driving sustainable urban logistics.

Recommendations

Based on the study findings, the following recommendations are proposed to enhance environmental sustainability in last-mile logistics through urban smart mobility innovations in Nairobi:

Logistics firms should invest more in advanced route optimization systems, real-time vehicle tracking, and automated dispatch tools to improve delivery efficiency and reduce fuel consumption. Training programs should be introduced to ensure employees can effectively use these technologies for maximum environmental benefit.

Stakeholders, including logistics providers and policymakers, should promote the wider adoption of electric vehicles (EVs), e-bikes, and other micro-mobility options. This can be supported through targeted subsidies, tax incentives, and financing schemes to lower the initial investment costs for small and medium-sized logistics operators.

County governments, in partnership with the private sector, should prioritize the development of urban consolidation centers, micro-depots, and a reliable network of public EV charging stations. Adequate infrastructure will enable logistics companies to adopt cleaner delivery methods and reduce inner-city congestion and emissions.

Industry associations and government agencies should facilitate forums and digital platforms that enable logistics firms to share resources, consolidate deliveries, and coordinate routes. Establishing trust-building mechanisms, such as transparent agreements and shared performance metrics, will help sustain collaboration over time.

Logistics firms should embed environmental sustainability targets into their corporate strategies and operational policies. Regular monitoring of greenhouse gas emissions, fuel consumption, and energy use should be adopted as standard practice to track progress and meet both regulatory and corporate sustainability goals.

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