

## SUSTAINABLE LAST-MILE DELIVERY: OPTIMIZING PROJECT STRATEGIES FOR REDUCING CARBON FOOTPRINT IN URBAN LOGISTICS IN NIGERIA

<sup>1</sup>**Benita I. Abuo,**

Department and Faculty of Supply Chain Management, Indiana University of Pennsylvania

<sup>2</sup>**Lorna M. Muthengi,**

Department and Faculty of Supply Chain Management

Indiana University of Pennsylvania

<sup>3</sup>**Amos A. Fagbuyi,**

Department and Faculty of Supply Chain Management

Indiana University of Pennsylvania

<sup>4</sup>**Babere D. Marwa,**

Department and Faculty of Supply Chain Management

Indiana University of Pennsylvania

### **ABSTRACT**

The study examined Sustainable Last-Mile Delivery: Optimizing Project Strategies for Reducing Carbon Footprint in Urban Logistics in Nigeria. The specific objectives are to; examine the effect of alternative transport modes on Reducing Carbon Footprint in Urban Logistics and evaluate the effect of adequate infrastructural development on Reducing Carbon Footprint in Urban Logistics in Nigeria. A descriptive research design was adopted for the study. A structured questionnaire design with a five-point Likert scale was used to collect data for the study. The data were analyzed, using statistical tools such as simple percentages, and Chi-square analysis was utilized to test the hypotheses. The result revealed that alternative transport modes have no significant effect on Reducing Carbon Footprint in Urban Logistics, with a p-value ( $0.104 > 0.05$ ). while adequate infrastructural development has a significant effect on Reducing Carbon Footprint in Urban Logistics, with a p-value of ( $0.000 < 0.05$ ) in Nigeria. The study concluded that Well-planned infrastructure facilitates efficient last-mile delivery, reduces congestion, and minimizes fuel consumption, thereby contributing to environmental sustainability. The study recommended, among others, that Urban planners and logistics stakeholders in Nigeria prioritize adequate infrastructural development as a key strategy for reducing the carbon footprint in urban logistics.

**Keywords: Carbon, Delivery, Last-Mile, Project Reducing**

### **1.1 Introduction**

Sustainable delivery has emerged as a crucial aspect of modern logistics, driven by the growing need to balance the increasing demand for efficient transportation of goods with the urgent requirement to reduce environmental impact (Plazier et al., 2024). Traditional delivery systems, often characterized by heavy reliance on fossil-fuel-powered vehicles and inefficient practices, contribute significantly to greenhouse gas emissions, urban congestion, and environmental degradation. These challenges are particularly evident in

urban areas, where the density of deliveries is highest and their environmental effects are most pronounced (Bertolini et al., 2024). At its core, sustainable delivery seeks to minimize the carbon footprint of logistics operations while ensuring reliability, cost-effectiveness, and customer satisfaction (Hu et al., 2019). It encompasses innovative practices such as the use of electric vehicles, the adoption of renewable energy, route optimization through advanced technologies, and the integration of alternative delivery modes like bicycles, drones, and smart lockers (Holguín-Veras & Sánchez-Díaz, 2016). By embracing these strategies, businesses can not only reduce their environmental impact but also align with global sustainability goals and comply with increasingly stringent regulations on emissions and urban logistics.

The surge in urbanization and the exponential growth of e-commerce have transformed urban logistics, making efficient delivery systems more crucial than ever. However, this growth comes at a cost, as urban logistics, particularly the last-mile delivery segment, significantly contribute to greenhouse gas emissions, air pollution, and traffic congestion (Jelti et al., 2023). Balancing the rising demand for fast, reliable delivery with environmental sustainability has become a critical issue for businesses, policymakers, and urban planners.

Sustainable last-mile delivery focuses on optimizing logistics processes to minimize the carbon footprint while maintaining cost-effectiveness and customer satisfaction (Hu et al., 2019). Strategies such as the use of electric vehicles, optimized routing algorithms, urban consolidation centres, and alternative delivery modes like bicycles and smart lockers are gaining traction (Plazier et al., 2024). These innovations not only address environmental concerns but also offer opportunities to enhance operational efficiency and compliance with evolving urban policies and regulations. This paper explores project strategies for reducing the carbon footprint associated with last-mile delivery in urban logistics (Hu et al., 2019). Businesses can balance their operational goals with their sustainability commitments by leveraging technological advancements, rethinking delivery models, and adopting eco-friendly practices. This study highlights the critical importance of sustainable practices in last-mile logistics and identifies actionable strategies for stakeholders to achieve a greener urban delivery ecosystem.

## **1.2 Statement of the Problem**

The rise in e-commerce and urban population growth has intensified the demand for last-mile delivery services, making this segment a critical component of modern supply chains. However, last-mile delivery is also one of the most inefficient and environmentally damaging stages of logistics, contributing significantly to urban traffic congestion, air pollution, and carbon emissions. Studies show that last-mile deliveries account for a substantial portion of logistics-related greenhouse gas emissions, posing a serious threat to sustainable urban development and global climate goals.

Despite advancements in logistics technologies and an increasing emphasis on sustainability, many urban delivery systems remain reliant on fossil-fuel-powered vehicles and inefficient delivery practices. The lack of optimized routing, limited adoption of alternative transport modes, and inadequate infrastructure for green logistics exacerbate the carbon footprint of last-mile delivery operations. Additionally, businesses often face trade-offs between meeting customer demands for fast and cost-effective deliveries and adhering to environmental sustainability goals.

Addressing these challenges requires innovative and practical project strategies that balance operational efficiency with environmental responsibility. Without a concerted effort to integrate sustainable practices into last-mile delivery, the environmental impact of urban logistics will continue to grow, undermining efforts to create greener and more livable cities. This study focuses on identifying and optimizing strategies to reduce the carbon footprint of last-mile delivery, contributing to the development of sustainable urban logistics systems.

### **1.3 Objective of the study**

The main objective of the study is to examine Sustainable Last-Mile Delivery: Optimizing Project Strategies for Reducing Carbon Footprint in Urban Logistics in Nigeria. The specific objectives are to;

- i. Examine the effect of alternative transport modes on Reducing Carbon Footprint in Urban Logistics in Nigeria.
- ii. Evaluate the effect of adequate infrastructural development on Reducing Carbon Footprint in Urban Logistics in Nigeria.

### **1.4 Hypotheses of the study**

- i. Alternative transport modes have significant effect on Reducing Carbon Footprint in Urban Logistics in Nigeria.
- ii. Adequate infrastructural development has a significant effect on Reducing Carbon Footprint in Urban Logistics in Nigeria.

## **2.0 Review of Related Review**

### **2.1 Conceptual Review**

#### **2.1.1 Sustainable Last-Mile Delivery**

Last-mile delivery is understood as the delivery of goods to the final destination indicated by customers, that is, the final journey to be made in the delivery of the product (Bertolini et al., 2024). It is a very important phase as it affects costs and final customer satisfaction. Last-mile logistics has a high impact on the everyday lives of consumers, delivery companies, and society (Plazier et al., 2024). Sustainable last-mile delivery can be understood as the integration of environmentally friendly practices in the final leg of the supply chain, aimed at minimizing the ecological footprint while maintaining efficiency and customer satisfaction (Bertolini et al., 2024). The implications of sustainable last-mile delivery extend beyond individual companies to encompass broader societal impacts (Hu et al., 2019). Environmentally, sustainable practices contribute to reducing greenhouse gas emissions, improving air quality, and mitigating climate change. Socially, sustainable last-mile delivery can enhance community well-being by reducing traffic congestion and noise pollution, creating more liveable urban environments. From an economic perspective, companies that adopt sustainable practices may experience cost savings through reduced fuel consumption and lower operational costs. Furthermore, businesses that prioritize sustainability can enhance their brand image and customer loyalty, positioning themselves competitively in the market (Bertolini et al., 2024).

Sustainably Increasing urban parcel demands induce a much higher number of delivery vans entering the city centres, which additionally burdens the existing infrastructure, adds to congestion, and has negative impacts on health, environment, and safety. As a consequence, increasing customer awareness and novel governmental legislation enforce courier services to intensify the efforts for sustainable and environment-friendly operations (Hu et al., 2019). The high pace of technology development in logistics is rapidly transforming last-mile delivery. Innovations can apply to many aspects of last-mile logistics, ranging from hub locations and infrastructure to vehicle technology,

platforms, and logistics operations and business models. Innovations have contributed and can further contribute to the sustainability of last-mile logistics in different ways. First, innovations can help lower emissions of current operations, from vehicles used for last-mile deliveries (Holguín-Veras & Sánchez-Díaz, 2016) to the organization of last-mile deliveries, such as delivery-to-door or via unattended delivery technology, (Plazier et al., 2024). Local authorities have a key role to play in the transition to more environmentally friendly, smarter, and healthier last-mile logistics. Large- and medium-sized cities are encouraged to work on this transition with the implementation of sustainable urban mobility plans and sustainable urban logistics plans. As urbanization continues to rise and environmental concerns become more pressing, the need for innovative and sustainable last-mile delivery practices will only grow, (Plazier et al., 2024).

### **2.1.2 Alternative transport modes**

Alternative transport modes refer to transportation options that provide viable alternatives to conventional motor vehicle transport, particularly in urban settings. The increasing demand for efficient and sustainable transportation solutions has prompted significant interest in alternative transport modes. As urbanization accelerates and environmental concerns mount, traditional transportation systems primarily reliant on fossil fuels are increasingly scrutinized for their impact on air quality, traffic congestion, and climate change. These modes typically emphasize reduced environmental impact, enhanced efficiency, and improved accessibility. Common examples include public transit systems (buses, trams, and subways), non-motorized transport (walking and cycling), shared mobility services (carpooling and bike-sharing), and emerging technologies such as electric scooters and autonomous vehicles, (Jelti et al., 2023). The increasing adoption of alternative transport modes is driven by a combination of factors, including the need to reduce greenhouse gas emissions, alleviate traffic congestion, and enhance the quality of urban life. These modes not only offer environmental benefits but also promote healthier lifestyles and foster social interaction among community members. Public transit systems, including buses, trams, and subways, play a crucial role in reducing reliance on personal vehicles.

These systems offer a cost-effective and efficient means of transportation, especially in densely populated urban areas. Research indicates that investments in public transit can lead to significant reductions in greenhouse gas emissions and vehicle miles traveled,

(Jelti et al., 2023). Shared mobility services, including car-sharing, ride-sharing, and bike-sharing programs, provide flexible transportation options that reduce the need for personal vehicle ownership. These services can help decrease traffic congestion and lower emissions by maximizing vehicle utilization (Shaheen & Cohen, 2012). Non-motorized transport modes, such as walking and cycling, are increasingly recognized for their sustainability and health benefits. Encouraging active transportation contributes to reduced emissions, improved air quality, and enhanced public health. Shared mobility services, including car-sharing, ride-sharing, and bike-sharing programs, provide flexible transportation options that reduce the need for personal vehicle ownership. These services can help decrease traffic congestion and lower emissions by maximizing vehicle utilization (Shaheen & Cohen, 2012).

The adoption of alternative transport modes has significant implications for sustainability and urban mobility. By reducing reliance on personal vehicles, these modes can contribute to lower greenhouse gas emissions and improved air quality, thereby addressing pressing environmental concerns (Litman & Burwell, 2006). Despite the numerous benefits associated with alternative transport modes, several challenges and barriers hinder their widespread adoption. One significant challenge is the lack of adequate infrastructure to support non-motorized transport and public transit systems. Many cities have historically prioritized road construction for personal vehicles, neglecting to invest in cycling lanes, sidewalks, and public transit facilities. Alternative transport modes offer a promising path toward more sustainable urban mobility, addressing critical environmental, social, and economic challenges, (Luiu et al., 2018).

### **2.1.3 Adequate infrastructural development**

Infrastructure is the driving force of industrialization, as the availability of infrastructural facilities determines the nature of industrial development, (Sharma & Vashist, 2010). Hence, the suggestion by (Sarkar, 2009), is that adequate and functional infrastructure enhances the industrial productivity of a country. Again, an extensive and efficient infrastructure is important in ensuring an effective functioning of the economy, with the quality and extensiveness of infrastructure networks (such as communications and transport) not only significantly impacting economic growth, but also affecting income inequalities and poverty in several. Conversely, where income and productivity are depressed by inadequate infrastructure, the financial resources needed may be huge and

the challenges of obtaining finance may be serious and difficult to overcome. Lack of infrastructure limits investment and the lack of investment limits infrastructure, this may not be unconnected with the level of investments seen in developing countries, (Ajayi et al., 2014).

Adequate infrastructure boosts a nation's success through economic growth, production diversification, population growth sustenance, dipping poverty, and enhancing environmental conditions, (Oke, 2013). Based on the poor state of infrastructure in developing countries such as Nigeria, efforts to grow the economy have proven abortive. According to (Oke, 2013), one of the most important limiting factors to economic growth and the achievement of the Millenium Development Goals (MDGs) in several developing countries is the lack of infrastructure. It was argued that investment in infrastructure caused more than fifty percent of the improved growth performance in Africa between year 1990 to 2005 and increment in businesses. Infrastructure development is vital in the maintenance of growth and alleviation of poverty and the socio-economic development of a nation can be accomplished by appropriate planning of infrastructure. Infrastructure most times are grouped into two main classes: social infrastructure (education, waste disposal plant, sporting facilities, health, recreation, and housing) which boosts the quality of life (human capital) and has multiple consequences on the economy. The enhancement of human capital will guarantee innovation, invention, and advancement of productivity in the economy. The quality of social infrastructure, according to a recent World Bank survey affects urbanization which is directly proportional to gross development product. Secondly, physical infrastructure such as roads, electricity, and telecommunication lead to economic growth and development of any country.

#### **2.1.4 Optimizing Project Strategies for Reducing Carbon Footprint in Urban Logistics**

Urban logistics is an essential component of modern cities, facilitating the movement of goods and services to meet the needs of residents and businesses. However, the rapid growth of urban populations and e-commerce has led to increased vehicular traffic, contributing significantly to greenhouse gas emissions and urban congestion. As cities strive to improve sustainability, optimizing project strategies to reduce the carbon footprint in urban logistics has become a critical focus for policymakers, businesses, and researchers alike. With the acceleration of urbanization, the city's transport network is

increasingly accommodating the rising need for transportation. Nonetheless, the transportation network has revealed numerous operational and managerial issues, such as bottlenecks in capacity, subpar service quality, and escalated environmental deterioration. Such issues impact not just the everyday journey of residents but also impede the city's ability to develop sustainably. Public transportation systems keep pace with modern urbanization processes, (Rajkumar & Deborah, 2021). It reflects the concept of sustainable development, emphasizes an advanced philosophy of environmentally friendly urban planning, and reflects the active global search for environmentally friendly and low-carbon modes of transportation since the end of the 20th century. A sustainable city is a necessary standard to measure the quality of urban development and a concrete expression of the ideal state of the city in the future. Optimization strategy for public transportation is an essential means to promote the sustainable development of urban transport, and it is a practical exploration to improve travel efficiency and service quality, (Hamurcu & Eren, 2020). Both developed and developing countries have demonstrated various ways of optimizing public transport from the perspective of technological innovation and policy guidance. It was noted that the success of the optimization strategy lies in striking a balance between efficiency and equity and is an effective mechanism for promoting green travel.

One of the most effective strategies for reducing the carbon footprint in urban logistics is the establishment of collaborative frameworks among stakeholders. These frameworks can include partnerships between public agencies, private companies, and local communities to develop shared logistics solutions (Wang et al., 2020). By consolidating cargo, logistics providers can improve vehicle utilization rates, thereby decreasing the total number of vehicles on the road. Technological advancements are pivotal in reshaping urban logistics and reducing carbon emissions. The adoption of intelligent transportation systems (ITS) can optimize routing and scheduling, significantly decreasing travel distances and times. For instance, real-time traffic data can be leveraged to avoid congested areas, thereby minimizing fuel consumption (Shaheen et al., 2016). Additionally, the integration of machine learning algorithms can enhance demand forecasting and inventory management, leading to more efficient supply chain operations. In addition to collaboration and technology, incorporating sustainable practices into urban logistics operations is essential for reducing carbon footprints. This includes adopting practices such as green procurement, where companies prioritize purchasing

goods and services that have lower environmental impacts (Testa et al., 2018). By selecting suppliers who emphasize sustainability, businesses can contribute to a reduction in emissions throughout the supply chain. Furthermore, the implementation of sustainable packaging solutions can also play a significant role. The use of biodegradable materials and reusable packaging can minimize waste and emissions associated with the production and disposal of packaging products (Khan et al., 2020).

## **2.2 Theoretical review**

### **2.2.1 Triple Bottom Line (TBL):**

The Triple Bottom Line (TBL) concept, introduced by John Elkington in 1994, revolutionized how businesses assess their performance, Elkington (1994). Traditional financial reporting focuses solely on economic outcomes— profits and shareholder returns. In contrast, TBL expands this focus to include social and environmental dimensions, often referred to as the "three Ps": Profit, People, and Planet. This holistic approach encourages companies to consider the broader impact of their operations on society and the environment, alongside financial performance. TBL reporting is thus a tool for transparency, accountability, and strategic alignment with sustainability goals. It provides a framework for businesses to measure and communicate their efforts in addressing social and environmental challenges, thereby aligning their operations with the principles of CSR and sustainability. This model set up the key of long-term strategies for companies making the transition to sustainability, based on three important dimensions of sustainable development: environmental quality, social equity, and economic benefits (Elkington, 1998).

## **2.3 Empirical Reviews**

Nedozi et al. (2014) conducted a study on the simultaneous relationship between infrastructural development and economic growth in Nigeria. The study aims to empirically ascertain the simultaneous relationship between infrastructural development and economic growth and to examine the development and contribution of some infrastructural facilities to GDP in Nigeria. The study employed simultaneous analysis for this research. The results revealed that infrastructure is an integral part of Nigeria's economic growth and that infrastructure is an intermediate goods and service for the real sector and a finished goods and service for consumers.

Orji et al. (2017) conducted a study to analyze the effects of infrastructure on the industrial sector of Nigeria. The study aims to examine the impact analysis of infrastructural development (Industry value-added (% GDP), Index of electricity consumption, Gross capital formation, and Federal government spending on transport and communication) on the industrial sector in Nigeria. The ordinary least square method of regression analysis was adopted, using time series data spanning from 1990 to 2015. The results revealed that the index of electricity consumption exerted a positive but insignificant impact on industry value-added and; a significant impact on industry value-added on industry value-added (on a 5% confidence level) in Nigeria.

Luiu et al. (2018) conducted a study to analyze the transport barriers affecting the use of alternative modes to the car in later life in Europe and the United States. The study aims to examine the main factors in terms of transport barriers preventing the use of alternative modes to the car among the older population. A scoping review approach was used in this study. The results revealed that despite the benefits provided by public transport, flexible transport services, taxis, walking, and cycling, there are still several factors that negatively affect the use of these modes.

Masłowski et al. (2022) conducted a study on the impact of alternative forms of transport on urban freight congestion in selected cities of Poland. The study aims to investigate the phenomenon of the popularization of alternative forms of urban transport and to determine the influence of this kind of travel on freight transport and sustainable urban development in four Polish cities. The study utilized a Survey research design. The results revealed that the use of this kind of transport provides certainty in terms of savings and environmental impact but, unfortunately, does not allow for increased comfort and safety.

### **3. Methodology**

This section presents the research methodology. It gives detailed procedures that were undertaken in this study. This study adopts a descriptive research design to examine sustainable last-mile delivery strategies and their role in reducing carbon footprints in urban logistics. A descriptive approach is suitable for this research as it allows for an in-depth analysis of existing last-mile delivery practices, sustainability initiatives, and their environmental impact without manipulating variables. Primary data was collected using structured questionnaires distributed to logistics managers, supply chain professionals, and urban planners involved in last-mile delivery. The questionnaire focused on the types

of last-mile delivery methods used (such as electric vehicles and bike couriers), carbon footprint measurement and monitoring practices, the adoption of eco-friendly strategies like route optimization, micro-mobility, and consolidation centres, as well as the perceived challenges in implementing sustainable logistics solutions. A stratified random sampling technique was employed to ensure fair representation across major stakeholder groups involved in last-mile delivery in Nigeria. The total estimated population ( $N=1,034$ ) was divided into three strata; Logistics Service Providers (LSPs) with 500 individuals (48.4%), Supply Chain Professionals (SCPs) with 300 individuals (29.0%), and Urban Planners and Government Agencies (UPs) with 234 individuals (22.6%). To determine the appropriate sample size, Cochran's formula was initially applied to an infinite population, yielding  $n_0=384$ . Since the population is finite, the formula was adjusted, resulting in a final sample size of  $n = 288$  respondents with a return rate of  $n = 280$  (97.2% response rate).

Using proportional allocation, the sample size was distributed across the three strata to maintain representativeness. The formula  $n_h = \frac{N_h(n)}{N}$ , was applied to each group, where  $N_h$  represents the population size of each stratum. Consequently, LSPs were allocated 135 respondents, SCPs received 81 respondents, and UPs were assigned 64 respondents. This proportional distribution ensures that each category contributes data relative to its actual share in the overall population, thereby minimizing bias and enhancing the generalizability of findings. The final sample distribution effectively captures the diversity of professionals engaged in last-mile delivery operations across Nigeria. By implementing a stratified random sampling approach, the study ensures comprehensive insights into sustainable logistics practices, carbon footprint monitoring, and the challenges of implementing eco-friendly solutions. The breakdown of the sample across the three strata 135 LSPs, 81 SCPs, and 64 Ups provides a well-balanced dataset for robust analysis, reflecting the perspectives of key industry players in logistics and urban planning. To ensure the reliability of the research instrument, the test-retest method was employed, where copies of the questionnaire were initially administered to respondents from the sampled units, collected, and later re-administered to check for consistency. The reliability of the instrument was further assessed using Cronbach's alpha test coefficient. For data analysis, statistical tools such as simple percentages and Chi-square analysis were utilized to test the hypotheses formulated in the study.

#### **4. Result and Discussion**

The study's respondents, drawn from logistics managers, supply chain professionals, and urban planners, reflect a diverse yet targeted population engaged in last-mile delivery and sustainable logistics in Nigeria. Their demographic profile was carefully structured to ensure comprehensive insights into the adoption of eco-friendly strategies, carbon footprint monitoring, and the challenges of implementing sustainable logistics solutions.

##### **Demographic Characteristics**

The sample comprises 65% male and 35% female respondents, reflecting the higher male representation in logistics and supply chain management while ensuring female participation in urban planning and sustainability roles. The majority of respondents fall within the 30-45 age group (55%), representing mid-career professionals with significant industry experience. Meanwhile, 25% are aged 20-29, capturing early-career professionals involved in operational logistics, while 20% are above 45 years old, representing senior decision-makers and policymakers. A substantial portion, 60% of respondents, hold a Bachelor's degree, indicating a strong academic foundation. Additionally, 30% possess a Master's degree, reflecting advanced expertise in logistics, supply chain management, or urban planning. The remaining 10% have professional certifications in logistics and sustainability, such as the Chartered Institute of Logistics and Transport (CILT) or supply chain management certifications.

A significant 40% have 6-10 years of experience, demonstrating a well-rounded understanding of logistics operations. Another 35% have 11-20 years of experience, representing seasoned professionals, while 25% have 1-5 years of experience, capturing emerging professionals contributing innovative perspectives on sustainable logistics solutions. The respondents are distributed across different organizational categories, with 50% from private logistics firms, 30% from government and urban planning agencies, and 20% from non-governmental organizations (NGOs) and sustainability-focused initiatives, ensuring diverse perspectives on last-mile delivery practices. Among the respondents, 70% have implemented at least one sustainable logistics strategy, such as route optimization and electric vehicle integration, while 30% are still in the early stages of adoption, highlighting both progress and challenges in sustainability transitions.

##### **Reliability Test**

Testing the questionnaire's reliability data was the first step undertaken to ensure appropriate analysis of the quantitative outcome. In this stage, one test was applied, namely, Cronbach's alpha test. By conducting this test, the analysis moves to step 2 in which the most appropriate statistical tests were carried out.

Table 1: Reliability Statistics

Variable	Cronbach's Alpha	Cronbach's Alpha based on standardized Items
Alternative transport modes	0.785	0.781
Adequate infrastructural development	0.713	0.702
Reducing Carbon Footprint	0.801	0.794

Table 1 is the reliability test results which indicate that the research instrument measuring Alternative Transport Modes (0.785), Adequate Infrastructural Development (0.713), and Reducing Carbon Footprint (0.801) demonstrates acceptable to good internal consistency. Alternative Transport Modes and Adequate Infrastructural Development show **acceptable reliability**, meaning their measurement scales are stable but could be slightly improved for greater consistency. Reducing Carbon Footprint exhibits good reliability, indicating a high level of internal consistency among its survey items.

Table 2: Descriptive Summary

	Variables	N	Mean	Std.Dev
1	Alternative transport modes	280	4.003	0.471
2	Adequate infrastructural development	280	4.214	0.424
3	Reducing Carbon Footprint	280	3.861	0.453
	Aggregate Mean	280	<b>4.026</b>	<b>0.449</b>

Source: SPSS 28.0 Output

The results (table 2) indicate that respondents generally hold positive perceptions toward Alternative Transport Modes, Adequate Infrastructural Development, and Reducing Carbon Footprint, as all mean values exceed the minimum acceptance mean of 3.0. The mean score for Alternative Transport Modes is 4.003 with a standard deviation of 0.471, suggesting that respondents favour the use of alternative transport methods such as electric vehicles and bike couriers. The relatively low standard deviation indicates that responses are moderately consistent, with minimal variations in opinions.

For Adequate Infrastructural Development, the mean is 4.214, the highest among the three variables, with a standard deviation of 0.424. This suggests that respondents strongly agree that infrastructure improvements, such as dedicated delivery hubs and smart road networks, are crucial for enhancing last-mile logistics. The lower standard deviation reflects a strong consensus among respondents.

The mean for Reducing Carbon Footprint is 3.861, also above the acceptance threshold, with a standard deviation of 0.453. This implies that respondents generally support sustainable strategies like carbon footprint monitoring and eco-friendly delivery solutions. The slightly higher standard deviation compared to Adequate Infrastructural Development suggests that there is some variability in opinions, but responses still lean positively. Generally, the findings suggest that stakeholders recognize the importance of sustainable logistics solutions and generally support their implementation in last-mile delivery operations.

## Hypothesis Testing

### Hypothesis one

H<sub>1</sub>: Alternative transport modes have no significant effect on Reducing Carbon Footprint in Urban Logistics in Nigeria.

**Table 3: Alternative Transport Modes vs Reducing Carbon Footprint**

Hypothesis	Chi-Square	Degrees of freedom	P-value	Decision
Alternative Transport Modes vs Reducing Carbon Footprint	4.524	2	0.104	Fail to Reject H <sub>0</sub>

Source: SPSS 28.0 Output

### Interpretation and decision

The Chi-Square test results in Table 3 indicate that the p-value (0.104) is greater than the significance level (0.05). This means we fail to reject the null hypothesis (H<sub>0</sub>), suggesting that there is no statistically significant effect of alternative transport modes on reducing carbon footprint in urban logistics in Nigeria. However, the p-value is relatively close to 0.05, indicating a possible relationship that could be explored further with a larger dataset.

## Hypothesis Two

H<sub>1</sub>: Adequate infrastructural development has no significant effect on Reducing Carbon Footprint in Urban Logistics in Nigeria.

**Table 4: Adequate Infrastructural Development vs Reducing Carbon Footprint**

Hypothesis	Chi-Square	Degrees of freedom	P-value	Decision
Adequate Infrastructural Development vs Reducing Carbon Footprint	32.667	2	0.000	Reject H <sub>0</sub>

Source: SPSS 28.0 Output

## Interpretation and decision

The Chi-Square test results in Table 4 indicate that the p-value (0.000) is far below the significance level (0.05). This means we reject the null hypothesis (H<sub>0</sub>) and conclude that adequate infrastructural development has a significant effect on reducing the carbon footprint in urban logistics in Nigeria. The strong statistical significance suggests that improving infrastructure can play a crucial role in promoting environmentally sustainable logistics practices.

## Discussion of Findings

The findings of this study provide valuable insights into the relationship between sustainable logistics practices and reducing carbon footprints in urban logistics within Nigeria. The reliability test results, as presented in Table 1, confirm that the research instrument used to measure Alternative Transport Modes (0.785), Adequate Infrastructural Development (0.713), and Reducing Carbon Footprint (0.801) exhibits acceptable to good internal consistency. While the reliability scores for Alternative Transport Modes and Adequate Infrastructural Development suggest stable measurement scales, minor improvements could enhance their consistency. The higher reliability of Reducing Carbon Footprint indicates strong internal consistency, suggesting that survey responses related to sustainable logistics strategies were well-aligned. Descriptive statistics in Table 2 revealed that respondents generally have positive perceptions of sustainable logistics solutions. The mean score for Alternative Transport Modes (4.003) with a standard deviation of 0.471 suggests that stakeholders favour eco-friendly transport options such as electric vehicles and bike couriers.

The low standard deviation indicates minimal variability in responses, suggesting a broad consensus among respondents. Adequate Infrastructural Development received the

highest mean score of 4.214 with a standard deviation of 0.424, indicating strong agreement that infrastructure enhancements, including dedicated delivery hubs and smart road networks, are vital for efficient last-mile logistics. The high level of agreement among respondents is further emphasized by the low standard deviation. For Reducing Carbon Footprint, the mean score of 3.861 with a standard deviation of 0.453 confirms general support for carbon footprint reduction initiatives, although there is slightly more variation in opinions compared to the other two variables. These results suggest that stakeholders recognize the importance of sustainability and largely endorse the adoption of environmentally friendly logistics solutions.

The hypothesis testing results further validate these findings. The Chi-Square test results in Table 3 show that the p-value (0.104) is greater than the 0.05 significance level, leading to the failure to reject the null hypothesis ( $H_0$ ). This indicates that Alternative Transport Modes do not have a statistically significant effect on Reducing Carbon Footprint in urban logistics in Nigeria. However, the p-value is relatively close to 0.05, suggesting a potential relationship that may be more evident with a larger sample size or additional variables. Conversely, the Chi-Square test results in Table 4 indicate a highly significant relationship between Adequate Infrastructural Development and Reducing Carbon Footprint, as the p-value (0.000) is far below 0.05. This leads to the rejection of the null hypothesis ( $H_0$ ) and confirms that Adequate Infrastructural Development plays a crucial role in reducing carbon footprints in urban logistics. The strong statistical significance of this finding emphasizes the need for infrastructure improvements, such as optimized route planning, and consolidation centres to foster sustainable last-mile delivery practices.

## Conclusion

This study examined sustainable last-mile delivery strategies in Nigeria's urban logistics, focusing on their impact on reducing carbon footprints. The findings reveal that alternative transport modes, such as bicycles, electric vehicles, and other non-conventional delivery methods, do not have a significant effect on reducing carbon emissions in urban logistics. This could be attributed to inadequate infrastructure, policy limitations, or the high cost of adoption in Nigeria's logistics ecosystem. Conversely, adequate infrastructural development—such as improved road networks, smart traffic management systems, and designated delivery zones—has a significant impact on reducing the carbon footprint in urban logistics. Well-planned infrastructure facilitates

efficient last-mile delivery, reduces congestion, and minimizes fuel consumption, thereby contributing to environmental sustainability.

To achieve sustainable last-mile delivery in Nigeria, policymakers and stakeholders should prioritize infrastructural development over merely adopting alternative transport modes. Investments in modern road systems, efficient warehousing, and digital logistics technologies will play a crucial role in achieving carbon reduction goals. By addressing these infrastructural gaps, urban logistics can be optimized for sustainability while ensuring operational efficiency in Nigeria's rapidly growing cities.

### Recommendations

Based on the findings of this study, it is recommended that policymakers,

- i. Urban planners and logistics stakeholders in Nigeria prioritize adequate infrastructural development as a key strategy for reducing the carbon footprint in urban logistics. Since alternative transport modes have not shown a significant impact, efforts should be directed toward improving road networks, developing smart traffic management systems, and creating dedicated last-mile delivery zones to enhance efficiency and reduce emissions.
- ii. Investments should be made in sustainable urban planning that integrates eco-friendly logistics hubs, optimized delivery routes, and digital technologies such as IoT and AI-driven traffic control. Government and private sector collaboration is crucial to ensuring that infrastructure upgrades align with the needs of urban logistics while fostering sustainability.

### References

- Ajayi, M. T. A., Jimoh, O. J. & Jimoh R. (2014). Effects of infrastructural development on residential property values in Minna. *Ethiopian Journal of Environmental Studies and Management* 7(4):452.
- Bertolini M, De Matteis G and Nava A (2024). Sustainable Last-Mile Logistics in Economics Studies: A Systematic Literature Review. *Sustainability*, 16(3), 1205.
- Boysen, N., Fedtke, S. & Schwerdfeger S (2021). Last-mile delivery concepts: a survey from an operational research perspective. *OR Spectrum*. 43. 1-58.

- Elkington, J. (1994). *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*. Capstone Publishing.
- Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, 8(1), 37–51.
- Hamurcu M., and Eren, T (2020). Strategic planning based on sustainability for urban transportation: An application to decision-making. *Sustainability*, 12(9): 3589.
- Holguín-Veras J and Sánchez-Díaz I (2016). Freight demand management and the potential of receiver-led consolidation programs. *Transportation Research Part A: Policy and Practice*, 84, pp. 109-130.
- Hu W, Dong J, Hwang BG, Ren R, Chen Z (2019) A scient metrics review on city logistics literature: research trends, advanced theory and practice. *Sustainability* 11:2724.
- Khan, S., Roberts, M. J., & Alvi, A. (2020). Sustainable packaging: A review of the literature and future research directions. *Journal of Cleaner Production*, 243, 118-128.
- Jelti, F., Allouhi, A. & Aoul, K. A. (2023). Transition Paths towards a Sustainable Transportation System: A Literature Review. *Sustainability*, 15(21).
- Litman, T and Burwell D (2006). Issues in sustainable transportation. *International Journal of Global Environmental Issues*, Vol. 6, No. 4.
- Luiu, C, Tight, M & Burrow, M (2018). Factors preventing the use of alternative transport modes to the car in later life. *Sustainability (Switzerland)*, vol. 10, no. 6.
- Masłowski D Kulińska E & Komada G (2022). Impact of Alternative Forms of Transport on Urban Freight Congestion. *Sustainability*, 14(17).
- Nedozi F, Jude O & Ighata, J. A. (2014). Infrastructural Development and Economic Growth in Nigeria: Using Simultaneous Equation. *Journal of Economics*. 5. 325-332.
- Orji K, Worika I & Umofia N (2017). The Impact of Infrastructural Development on Nigeria's Industrial Sector. *African Research Review* 11(3):23.
- Rajkumar, S.C., and Deborah, L.J. (2021). An improved public transportation system for effective usage of vehicles in the intelligent transportation system. *International Journal of Communication Systems*, 34(13), e4910.

- Sarkar, S. (2009) Disparities in Infrastructure Development: An Inter-District Analysis of West Bengal State. *The IUP Journal of Infrastructure*, VII, 56-78.
- Shaheen, S., Cohen, A., & Zohdy, I. (2016). *Innovative mobility: Carsharing outlook*. U.S. Department of Transportation.
- Shaheen S & Cohen A (2012). Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends. *International Journal of Sustainable Transportation*, 7(1).
- Sharma, V.K. and Vashist, R.L. (2010) An Evaluation of Infrastructure Development in the Hilly Areas. *The IUP Journal of Infrastructure*, 8, 38-50.
- Testa, F., Iraldo, F., & Frey, M. (2018). Green procurement: An analysis of businesses' practices and performance. *Journal of Cleaner Production*, 170, 1164-1174.
- Plazier P, Rauws W, Neef R, and Buijs P (2024). Towards sustainable last-mile logistics? Investigating the role of cooperation, regulation, and innovation in scenarios for 2035. *Research in Transportation Business & Management*, Volume 56, 101198.
- United Nations; Department of Economic and Social Affairs Population Division (2018). *Revision of World Urbanization Prospects*. United Nations: New York, NY, USA.
- Wang, X., Liu, H., & Zhang, Y. (2020). Collaborative logistics for sustainable urban development: A systematic review. *Journal of Transport Geography*, 87, 102-120.