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Towards Sustainable Transport in Developing Economies: Green Logistics Practices and Challenges in Nigeria

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Abstract

The escalating global imperative to mitigate anthropogenic climate change has intensified scholarly and policy discourse on green logistics as a critical component of sustainable supply chain management (SSCM). The logistics and transportation sector, while indispensable to economic growth and trade facilitation, remains a major contributor to greenhouse gas (GHG) emissions, fossil fuel consumption, and environmental externalities. This study critically examines the barriers and opportunities associated with green logistics adoption in developing economies, using Kagibo Transportation Company in Kaduna State, Nigeria, as an empirical case study. A convergent mixed-methods research design was employed, integrating longitudinal quantitative performance data (2020-2024) with qualitative insights obtained from structured interviews and customer feedback. The quantitative analysis reveals that the implementation of incremental sustainability interventions—including route optimization using fleet telematics, preventive maintenance regimes, and fuel-efficiency monitoring—resulted in an estimated 86% reduction in carbon dioxide (CO₂) emission intensity and a twofold increase in fuel cost savings over the five-year period. These operational efficiencies also contributed to improved fleet reliability and reduced lifecycle operating costs. However, qualitative findings indicate that adoption remains constrained by systemic barriers, including limited access to green financing, inadequate transport infrastructure, weak regulatory enforcement, technological capacity deficits, and organizational inertia. Comparative benchmarking shows that Kagibo's annual CO₂ emission reduction rate (4-6%) remains below global best-practice levels observed in countries such as South Africa (8-10%) and Germany (12-15%), underscoring the influence of institutional and technological ecosystems on sustainability performance. Interpreted through the lenses of the Triple Bottom Line, Ecological Modernization Theory, and Systems Theory, the findings demonstrate that effective green logistics transitions require an integrated framework encompassing technological innovation, institutional strengthening, and policy coordination. The study concludes that green logistics adoption is both technically feasible and economically advantageous in resource-constrained contexts, offering a viable pathway for aligning environmental sustainability with operational efficiency and long-term competitiveness in Nigeria's transport sector.

Keywords

Green logistics;
Sustainable development;
Transportation;
Supply chain;
Triple Bottom Line;
Ecological Modernization;
Systems Theory

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1. Introduction

The transportation and logistics sector plays a pivotal role in economic development by facilitating trade, mobility, and market integration. However, it is also one of the most significant contributors to environmental degradation, accounting for a substantial share of global greenhouse-gas emissions, air pollution, and energy consumption. Recent estimates indicate that transport-related fuel combustion remains a major driver of carbon dioxide (CO₂) emissions worldwide, with freight transport emissions growing faster in developing economies due to rapid urbanization, expanding consumer markets, and inadequate infrastructure (IEA, 2023; UNEP, 2023). This dual role of transport as both an economic enabler and an environmental stressor has intensified scholarly and policy interest in sustainable transport systems, particularly the adoption of green logistics practices.

Green logistics refers to the integration of environmental considerations into logistics and supply chain operations, including transportation, warehousing, packaging, inventory management, and reverse logistics, with the aim of minimizing ecological impacts while maintaining operational efficiency (McKinnon et al., 2015; Tseng et al., 2015). Within the broader sustainable development discourse, green logistics aligns with the Triple Bottom Line framework, which emphasizes the simultaneous pursuit of economic viability, environmental protection, and social well-being (Elkington, 1997). Globally, evidence suggests that practices such as route optimization, fleet modernization, digital logistics systems, energy-efficient warehousing, and alternative fuels can reduce emissions, lower costs, and enhance competitiveness (Behrends & Flodén, 2021; Kim & Lee, 2021; Ye, 2024).

Despite growing global momentum, the adoption of green logistics remains uneven, particularly in developing economies. In sub-Saharan Africa, logistics systems are often

constrained by aging vehicle fleets, poor road infrastructure, unreliable energy supply, limited access to green finance, and weak regulatory enforcement (Akinbami & Fadare, 2021; Setyadi et al., 2023; Pozniak et al., 2024). Nigeria exemplifies these challenges. As Africa's largest economy and most populous country, Nigeria relies heavily on road-based freight transport, which dominates over rail and inland waterways. This dependence, combined with congested urban corridors, inefficient fleet management, and policy fragmentation, has intensified emissions, fuel inefficiencies, and urban air-quality problems, with measurable implications for public health and social well-being (Adeyemi & Osinowo, 2023; Oni & Oyesiku, 2021).

Although Nigeria has articulated commitments to climate mitigation through its Nationally Determined Contribution (NDC) and related environmental policies, translation into firm-level logistics practices remains limited (Federal Ministry of Environment, 2021; Adedoyin et al., 2023). Existing studies highlight persistent barriers to green logistics adoption, including high upfront investment costs, limited technical capacity, organizational resistance, and inconsistent policy enforcement (Adebayo, 2022; Aliyu & Sulaiman, 2022; Bassey & Ahmed, 2024). At the same time, emerging evidence suggests that incremental practices—such as improved fleet maintenance, digital route planning, circular logistics, and ICT-enabled monitoring—can generate tangible environmental and economic benefits even in resource-constrained contexts (Okeke et al., 2023; Chinonso & Ayoola, 2024).

Notwithstanding this growing body of literature, important gaps remain. Much of the existing research focuses on multinational corporations or large urban centers, particularly Lagos, with limited attention to indigenous small and medium-sized enterprises (SMEs) and subnational contexts, especially in Northern Nigeria (Onwuegbuzie & Anozie,

2023; Chukwu & Ahmed, 2023). Moreover, there is insufficient empirical evidence on how global green logistics frameworks translate into practical realities within developing-economy transport systems characterized by infrastructural deficits and institutional constraints. Understanding these dynamics is essential for advancing sustainable transport transitions that are both context-sensitive and scalable.

Against this backdrop, this study examines green logistics practices and challenges in Nigeria within the broader discourse on sustainable transport in developing economies. By synthesizing global sustainability frameworks with Nigeria-specific evidence, the paper seeks to illuminate the operational, institutional, and systemic factors shaping green logistics adoption. In doing so, it contributes to policy and academic debates by highlighting pathways through which environmentally responsible logistics can support sustainable development, climate goals, and socio-economic resilience in Nigeria and comparable developing-country contexts.

2. Literature Review

Conceptual Foundations of Green Logistics

Green logistics has emerged as a critical component of sustainable transport and supply chain management, focusing on minimizing the environmental impacts of logistics activities while preserving economic efficiency and service quality. It encompasses environmentally responsible practices across transportation, warehousing, packaging, inventory management, and reverse logistics (McKinnon et al., 2015; Tseng et al., 2015). Central to the concept is the reduction of greenhouse-gas emissions, energy consumption, waste generation, and local environmental externalities such as noise and air pollution (Karia & Asaari, 2016).

The evolution of green logistics is closely linked to broader sustainability frameworks, particularly the Triple Bottom Line (TBL),

which integrates economic performance, environmental stewardship, and social responsibility (Elkington, 1997; Carter & Rogers, 2008). In logistics contexts, this implies balancing cost efficiency and competitiveness with emission reductions and improved social outcomes, including occupational health and community well-being. Studies in both developed and emerging economies confirm that firms adopting green logistics practices often experience operational efficiencies, fuel savings, and enhanced corporate reputation, although outcomes depend on institutional and infrastructural contexts (Kim & Lee, 2021; Ismail et al., 2022).

Green Logistics and Sustainable Transport Systems

Sustainable transport systems aim to provide mobility and freight services that meet present economic and social needs without compromising environmental integrity or future generations' welfare (Banister, 2020; Rodrigue, 2020). Within this framework, freight transport is increasingly recognized as a major sustainability challenge due to its reliance on fossil fuels and road-based systems, particularly in developing economies (UNEP, 2023).

Green logistics contributes to sustainable transport by promoting strategies such as route optimization, modal shifts, fleet modernization, alternative fuels, and energy-efficient warehousing (Behrends & Flodén, 2021; Tiwari & Mishra, 2022). Empirical evidence suggests that integrating these strategies can significantly reduce emissions while maintaining logistics performance. For example, smart logistics systems and telematics have been shown to improve fleet efficiency and reduce fuel consumption (Zhang & Wang, 2022; Okeke et al., 2023). However, the feasibility of these measures varies widely across regions, depending on infrastructure quality, policy support, and access to technology.

Theoretical Perspectives Informing Green Logistics Adoption

Three theoretical perspectives are particularly relevant to understanding green logistics adoption in developing economies.

First, the Triple Bottom Line framework emphasizes the need for firms to internalize environmental and social costs alongside economic objectives (Elkington, 1997). In logistics, this framework supports the integration of emission accounting, worker welfare, and community impacts into decision-making processes (Ismail et al., 2022).

Second, Ecological Modernization Theory (EMT) posits that environmental improvements can be achieved through technological innovation, institutional reform, and market-based mechanisms rather than through economic contraction (Jänicke, 2020; Mol & Sonnenfeld, 2020). Applied to logistics, EMT highlights the role of ICT, cleaner vehicles, and regulatory incentives in decoupling transport growth from environmental degradation (Sun et al., 2022; Li & Zhang, 2022).

Third, Systems Theory views logistics networks as interconnected systems in which changes in one component (e.g., transport technology) affect others (e.g., costs, emissions, organizational behavior) (von Bertalanffy, 1968; Mensah & Oppong, 2021). This perspective is particularly valuable in developing economies, where infrastructural, financial, and institutional constraints interact to shape sustainability outcomes.

Global Evidence on Green Logistics Practices

International experience demonstrates that supportive policy frameworks and technological innovation are critical to successful green logistics transitions. In Europe, countries such as Germany and the Netherlands have implemented coordinated strategies combining regulatory standards, fiscal incentives, and digital logistics platforms, resulting in substantial emission

reductions and efficiency gains (Blauwens et al., 2022; Scholz et al., 2023). Japan's Eco-Rail Mark program illustrates how modal shifts and renewable-powered logistics facilities can reduce freight emissions while enhancing reliability (Nakayama & Takeda, 2021).

In emerging economies, evidence from Asia and parts of Africa shows that ICT-enabled logistics, alternative fuels, and circular logistics practices can deliver measurable sustainability benefits when adapted to local contexts (Gupta et al., 2021; Setyadi et al., 2023). However, studies consistently emphasize that without strong institutional support and infrastructure investment, adoption remains incremental rather than transformative (Nasir et al., 2023; Ye, 2024).

Green Logistics in Africa and Developing Economies

In sub-Saharan Africa, green logistics adoption is shaped by unique structural challenges, including limited rail networks, high dependence on road transport, energy insecurity, and financial constraints faced by indigenous firms (Agyabeng-Mensah et al., 2023; Pozniak et al., 2024). Organizational resistance and low environmental awareness further constrain adoption, particularly among SMEs (Aliyu & Sulaiman, 2022; Yusuf & Salisu, 2024).

Nevertheless, African case studies highlight emerging opportunities. Policy-driven initiatives such as South Africa's Green Freight Transport Strategy demonstrate that targeted incentives and regulatory clarity can accelerate sustainability transitions (Gumede & Dlamini, 2022). Circular logistics practices and reverse logistics are also gaining traction among SMEs, offering pathways to reduce waste and resource use with relatively low capital investment (Bernon et al., 2018; Chinonso & Ayoola, 2024).

Nigerian Context: Practices, Barriers, and Opportunities

Nigeria's logistics and transport sector is characterized by heavy reliance on road transport, aging vehicle fleets, and persistent infrastructure deficits, all of which contribute to high emissions and operational inefficiencies (Akinbami & Fadare, 2021; Chukwu & Ahmed, 2023). Urban logistics challenges, including congestion and weak land-use-transport integration, further exacerbate environmental impacts in major cities (Okafor & Anichebe, 2023).

Empirical studies identify several barriers to green logistics adoption in Nigeria. These include high upfront costs of cleaner technologies, limited access to green finance, weak enforcement of environmental regulations, and fragmented policy frameworks (Adebayo, 2022; Adedoyin et al., 2023; Bassey & Ahmed, 2024). Organizational and cultural factors—such as limited technical expertise and resistance to change—also play a significant role (Afolabi & Ekundayo, 2023; Aliyu & Sulaiman, 2022).

At the same time, opportunities exist. ICT tools, digital fleet management systems, and eco-driving practices have shown potential to reduce fuel consumption and emissions in Nigerian SMEs (Eze & Ogunleye, 2024; Okeke et al., 2023). Customer awareness of environmental issues is increasing, creating market incentives for firms that demonstrate sustainability commitments (Onwuegbuzie & Anozie, 2023). National policy instruments, including Nigeria's NDC Implementation Plan, provide a strategic framework that could support greener logistics if effectively implemented (Federal Ministry of Environment, 2021).

Research Gaps

Despite growing scholarly attention, several gaps persist in the literature. First, there is limited firm-level empirical evidence on green logistics adoption among indigenous SMEs, which dominate Nigeria's transport sector. Second, most Nigerian studies focus on Lagos

and southern urban centers, leaving northern regions underrepresented. Third, few studies integrate operational performance data with stakeholder perceptions to assess both economic viability and social readiness for sustainability transitions. Finally, there is insufficient analysis of how global green logistics frameworks can be adapted to Nigeria's infrastructural and institutional realities.

Addressing these gaps is essential for advancing sustainable transport in developing economies. This study contributes to the literature by examining green logistics practices and challenges in Nigeria through a context-sensitive lens, integrating global theory with local evidence to inform both policy and practice.

3. Methodology

This study employed a convergent parallel mixed-methods design, combining quantitative and qualitative approaches to examine green logistics adoption. Quantitative data captured measurable logistics performance indicators, including fuel costs, emissions reductions, and operational efficiency, while qualitative data explored employee and customer perceptions of sustainability initiatives. Both data strands were collected concurrently, analyzed separately, and integrated at the interpretation stage to ensure triangulation and enhance validity.

A case study approach was adopted, focusing on Kagibo Transportation, a medium-sized logistics firm in Kaduna State, Nigeria. This strategy enabled an in-depth examination of firm-level practices, stakeholder perspectives, and contextual barriers within a real-world operational setting (Yin, 2018).

The study population comprised employees (N = 130) and customers (N = 600), yielding a total population of approximately 730. Using Yamane's (1967) sampling formula at a 10% margin of error, a sample size of 88

respondents was determined. Stratified random sampling ensured proportional representation, consisting of 16 employees and 72 customers, further categorized into frequent and infrequent users.

Primary data were collected through structured questionnaires administered to employees and customers, alongside semi-structured interviews with managerial staff. Secondary data were obtained from Kagibo Transportation's annual reports (2021-2024), policy documents, and relevant academic literature.

Quantitative data were analyzed using descriptive statistics, while qualitative interview data were subjected to thematic analysis. Findings from both strands were subsequently integrated to provide a comprehensive understanding of the

operational, organizational, and contextual dynamics influencing green logistics adoption.

4. Results

Operational Performance Indicators of Green Logistics Practices

Operational data obtained from Kagibo Transportation covering the period 2020-2024 show incremental but consistent improvements in environmental and cost-efficiency performance following the introduction of green logistics measures. These measures primarily included route optimization, improved fleet maintenance schedules, and preliminary trials of low-emission vehicles.

Table 1 presents the key green logistics performance indicators over the five-year period.

Table 1: Green Logistics Impact Metrics at Kagibo Transportation (2020-2024)

Year	CO ₂ Emissions Reduction (tonnes)	Fuel Cost Savings (USD)	Change in Operational Efficiency (%)
2020	1,500	20,000	15
2021	1,800	25,000	18
2022	2,200	30,000	20
2023	2,500	35,000	22
2024	2,800	40,000	24

Source: Kagibo Transportation Annual Reports (2020-2024)

As shown in Table 1, CO₂ emissions reductions increased steadily from 1,500 tonnes in 2020 to 2,800 tonnes in 2024. This represents an overall increase of approximately 86% over the study period. Similarly, fuel cost savings rose consistently, doubling from USD 20,000 to USD 40,000, while operational efficiency improved from 15% to 24%. The pattern suggests that incremental green logistics

interventions yielded cumulative environmental and economic benefits over time.

Stakeholder Awareness and Perceptions of Green Logistics

Survey data collected from employees and customers (n = 88) reveal variations in awareness, perceptions, and perceived constraints related to green logistics adoption

at Kagibo Transportation. Among 16 employees, 62% reported awareness of green logistics concepts and practices. 50% identified financial constraints as the most significant barrier to adoption. 44% indicated inadequate infrastructure, particularly poor road conditions and limited charging facilities, as a major constraint, while only 31% believed that Kagibo currently possesses sufficient technical expertise to transition to cleaner logistics technologies.

Among 72 customers, 70% expressed a preference for logistics companies that demonstrate environmental responsibility. 46% indicated a willingness to pay slightly higher service charges for logistics services

with verified sustainability benefits. 39% reported limited awareness of Kagibo's existing eco-efficiency initiatives. Overall, the results indicate stronger sustainability expectations among customers than internal confidence among employees, alongside a notable gap in communication of sustainability efforts to service users.

Comparative Performance: Kagibo and Global Benchmarks

To contextualize Kagibo's performance, its average annual CO₂ emissions reduction rate was compared with selected international benchmarks in the logistics sector. Table 2 summarizes the comparative results.

Table 2: Comparative Average Annual CO₂ Reduction in Logistics

Context	Average Annual CO₂ Reduction (%)	Key Characteristics
Kagibo Transportation (Nigeria)	4-6%	Incremental efficiency measures; no fleet electrification
South Africa	8-10%	Supported by Green Freight Transport Strategy
Germany	12-15%	Extensive EV fleets, modal shifts, strong policy incentives
Japan	10-12%	Rail-based freight, solar-powered logistics hubs

Sources: Kagibo Transportation (2020-2024); Gumede & Dlamini (2022); Scholz et al. (2023); Nakayama & Takeda (2021)

The comparison shows that although Kagibo has achieved measurable progress, its emissions reduction rate remains significantly lower than those recorded in countries with advanced green logistics infrastructure and

policy support. This highlights the influence of structural and institutional contexts on firm-level sustainability outcomes.

Systemic Barriers to Green Logistics Adoption

Findings from survey responses and managerial interviews indicate that barriers to green logistics adoption at Kagibo Transportation are interrelated rather than isolated. These barriers were synthesized into a conceptual framework presented in **Figure 1**.

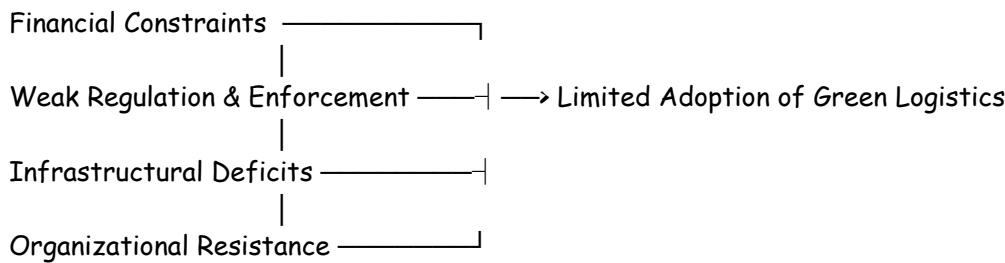


Figure 1: Barriers to Green Logistics Adoption at Kagibo Transportation

The framework illustrates how financial limitations, weak regulatory enforcement, infrastructural deficits, and organizational resistance collectively constrain the scale and pace of green logistics adoption. The results suggest that operational inefficiencies and slow sustainability transitions emerge from the interaction of multiple systemic factors rather than single-point failures.

5. Discussion of Results

The results demonstrate that Kagibo's green logistics initiatives align strongly with the economic and environmental dimensions of the Triple Bottom Line (Elkington, 1997). Fuel cost savings and efficiency gains confirm that sustainability-oriented practices can enhance firm performance, corroborating evidence from African and emerging economy contexts (Ismail et al., 2022; Joachimsthaler et al., 2024). However, the social dimension remains underdeveloped. Limited stakeholder awareness and weak communication reduce opportunities for customer engagement and employee buy-in. Previous studies in Nigeria similarly observe that sustainability efforts often remain internally focused, with minimal external disclosure or social integration

(Adeyemi & Osinowo, 2023; Onwuegbuzie & Anozie, 2023).

Ecological Modernization Theory emphasizes the role of technological innovation and institutional reform in reconciling economic growth with environmental protection (Mol & Sonnenfeld, 2020; Jänicke, 2020). Kagibo's experience illustrates the limits of ecological modernization in contexts where supportive institutions are weak. Unlike firms in Germany or Japan, Kagibo operates without subsidies for clean vehicles, reliable charging infrastructure, or robust regulatory enforcement. This finding aligns with Nigerian studies highlighting fragmented environmental governance, limited access to green finance, and inconsistent enforcement as major constraints on sustainable transitions in transport and logistics (Adedoyin et al., 2023; Bassey & Ahmed, 2024; Yusuf & Salisu, 2024).

The interlinked nature of financial, infrastructural, regulatory, and organizational barriers supports the application of Systems Theory (von Bertalanffy, 1968). Organizational resistance identified among employees mirrors findings by Aliyu and Sulaiman (2022), who argue that cultural inertia and skills gaps can

undermine sustainability initiatives even when economic benefits are evident. From a systems perspective, isolated interventions such as fleet upgrades without regulatory incentives or training are unlikely to produce transformative outcomes. Instead, coordinated interventions across policy, infrastructure, finance, and organizational learning are required (Agyabeng-Mensah et al., 2023; Wilson et al., 2024).

The modest performance of Kagibo relative to global benchmarks underscores the need for context-sensitive policy interventions. Rather than immediate large-scale electrification, a phased transition emphasizing driver eco-training, digital route planning, fleet retrofitting, and improved maintenance regimes may be more feasible for Nigerian SMEs (Okonkwo et al., 2023; Eze & Ogunleye, 2024). At the policy level, alignment with Nigeria's Nationally Determined Contribution (Federal Ministry of Environment, 2021) requires incentives such as tax reliefs, concessional financing, and coordinated governance structures to support green logistics adoption across the transport sector.

This study contributes to the literature by providing empirical evidence from an indigenous logistics SME in Northern Nigeria, an area underrepresented in sustainability research. It demonstrates that incremental green logistics practices can yield tangible benefits even under severe structural constraints, while also illustrating how systemic barriers limit the pace and scale of sustainability transitions in developing economies (Eze & Chukwu, 2022; Setyadi et al., 2023).

6. Conclusion and Future Scope

This study examined the adoption and performance implications of green logistics practices at Kagibo Transportation in Kaduna State, Nigeria. The findings show that incremental green logistics measures such as route optimization, improved fleet maintenance, and efficiency-focused operations have produced measurable environmental and economic benefits, including reduced CO₂ emissions, fuel cost savings, and improved operational efficiency. However, the scale of these gains remains modest when compared with global benchmarks, largely due to systemic barriers related to finance, infrastructure, regulatory enforcement, and organizational capacity. Overall, the study concludes that green logistics is achievable and beneficial in the Nigerian context, but meaningful progress requires coordinated, system-oriented interventions beyond firm-level efforts alone. These recommendations collectively emphasize the need for integrated firm-level, institutional, and infrastructural actions to accelerate green logistics adoption in Nigeria.

1. Kagibo Transportation and similar SMEs should adopt a phased transition strategy, beginning with cost-effective measures such as digital route planning, driver eco-training, and fleet retrofitting, before progressing to capital-intensive options like low-emission or electric vehicles.
2. Government agencies should provide targeted incentives such as tax reliefs, concessional financing, and pilot grants to encourage green logistics adoption, while strengthening regulatory enforcement to create a level playing field for environmentally responsible firms.

3. Strategic investment in transport infrastructure, including improved road networks and alternative-fuel charging facilities, should be pursued through public-private partnerships to reduce operational risks associated with green logistics technologies.
4. Logistics firms should enhance internal training to address skills gaps and resistance to change, while externally communicating sustainability initiatives through reporting, branding, and customer engagement to improve awareness and market competitiveness.

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