VOL. 10 NO. 9,
NOVEMBER, 2025
E-ISSN 3026-958X
P-ISSN 3027-1169

African Scholar Publications & Research International
www.africanscholarpub.com

Journal of Science Innovation & Technology Research (JSITR)

Technology Transfer and Green Logistics Integration: A Policy-Oriented Framework for Sustainable Logistics Firms in Nigeria

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DOI: https://doi.org/10.70382/ajsitr.v10i9.077

Abstract

Technological progress and innovations play a central role in revolutionizing green logistics management, boosting efficiency, sustainability, and environmental stewardship. With the logistics industry advancing, digital tools, automation, and smart solutions serve as vital drivers for eco-friendly supply chains. This study aims to identify key factors shaping enterprises' green logistics practices, assess how targeted technologies bolster sustainable operations, and offer policy suggestions to strengthen green logistics in Nigeria, in line with UN Sustainable Development Goals (SDGs) 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure), and 13 (Climate Action). The research employed formal methods drawing on primary and secondary data. Results indicate that technological preparedness and internal competencies are the primary drivers, while regulatory pressures take a backseat and contrasting trends in developed nations. The authors recommend tailored policies for Nigeria, such as government incentives for digital upgrades, sustainable procurement, and waste reduction. This framework also applies to other developing countries for analyzing factors' effects on green logistics. Green logistics has emerged as a worldwide imperative, with these policy ideas helping address environmental challenges to foster green growth

and SDGs particularly 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure), and 13 (Climate Action). Transportation firms now prioritize not just profits but also operational shifts for global sustainability. The research underscores the pressing need for targeted investments in cutting-edge technologies to advance green logistics in Nigeria and similar emerging markets.

Keywords: Technology Transfer, Green Logistics, Innovation, Sustainable Development Goals, Supply Chain Operations Reference.

Introduction

Here's a paraphrased version of the provided text, rephrased for clarity, conciseness, and smoother flow while retaining the original academic tone and structure: A strategic response to emerging global production trends involves adopting top-tier supply chain (SC) management practices that prioritize sustainability. This aligns seamlessly with the United Nations' Sustainable Development Goals (SDGs) 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure), and 13 (Climate Action). Green Supply Chain Management (GSCM) integrates all stakeholders to secure a lasting competitive edge. GSCM encompasses green procurement, manufacturing, materials handling, distribution, marketing, reverse logistics, product design, and customer collaboration. The "green" aspect highlights the SC's environmental impact. Srivastava outlines GSCM's evolution from reactive environmental monitoring to proactive strategies via the "Rs" (Reduce, Reuse, Rework, Refurbish, Reclaim, Recycle, Remanufacture, Reverse logistics, etc.). Karimi et al. (2023) describe it as embedding environmental considerations into inter-organizational activities, using a life-cycle approach from design and materials to manufacturing, sales, and recovery to optimize ecological benefits and drive organizational growth. Kosova et al. (2023) emphasize how GSCM applies key sustainability principles, showcasing green technologies and practices that cut costs, boost efficiency, and promote savings.

GSCM concepts are well-established, yet no universal policy exists for their organizational rollout. To enhance GSCM performance, systematic, prioritized measures are essential. Advanced environmental practices demand SC-wide actor integration, including information-sharing and knowledge-transfer networks among manufacturers, suppliers, and customers. These networks, built on mutual trust, strengthen Knowledge and Technology Transfer (KTT). KTT with customers and stakeholders enables firms to meet business, environmental, and social sustainability targets. Robust information exchange fosters long-term SC partnerships and performance gains (Oladele, 2021).

Ye and Zhang (2025) note that product- and process-based innovations are readily

observable. Through strategic repositioning, firms can launch such innovations to enter new markets, enhance branding, and gain competitive edges. A company's technological innovation hinges on rapid new-product development or process upgrades that are key to survival and sustainability. Frehe and Teuteberg (2017) empirically showed that technological innovation elevates GSCM performance. Innovations demand R&D, knowledge assets, advanced materials, and resources, with KTT as the core enabler. Yunlin (2023) defines KTT as transferring technology or knowledge across entities. Literature links GSCM to innovation, GSCM to KTT, and KTT to innovation separately, but a systematic review reveals no prior study examining their interplay holistically.

While GSCM, KTT, and innovation have been studied extensively, they remain siloed research areas, creating a gap in understanding their interconnections. This paper's novelty lies in unifying these perspectives, offering fresh insights and aiding firms in justifying green SC adoption.

Thus, this study examines the interplay among GSCM, KTT, and innovation. We built a conceptual framework via systematic literature review and validated it using Hsu's (2024) two-stage KTT-GSCM Multicriteria Model. Stage one identifies factors linking GSCM, KTT, and innovation, analyzing their influences via the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. Stage two provides detailed solutions for achieving green logistics in Nigeria through technology transfer, including short- and long-term timelines.

Key contributions include:

1. A literature-driven conceptual framework exploring GSCM, KTT, and innovation linkages for academia and industry.
2. The KTT-GSCM Multicriteria Model, mapping influence directions among these elements.
3. Empirical validation of their direct relationships, unexamined previously, clarifying their roles in green SCs.
4. Practical tools for firms to assess how their green practices, KTT, and innovation compare against suppliers, customers, and rivals.

This paper is structured as follows: Section 1 contextualizes the topic, states the problem and objectives, and outlines the structure. Section 2 details the literature-based conceptual framework. Section 3 covers the methodology (systematic review and KTT-GSCM model development). Section 4 presents and discusses results. Section 5 offers conclusions and recommendations.

Research Problem

The 2023 Nigerian Logistics Association Report, beyond evaluating digital transformation in logistics firms, confirmed rising interest and recognition of its vital role. Yet, companies encounter major obstacles, including: (1) limited awareness of digital transformation's benefits, (2) underdeveloped transport infrastructure, (3) technology deployment risks and ROI uncertainties, (4) steep investment costs, (5) inadequate cybersecurity, (6) incompatible

enterprise IT systems, (7) insufficient funding, (8) poor coordination and data sharing, (9) employee and managerial resistance to change, (10) weak digital skills and low-tech workforce, and (11) absent vision or strategy.

From 2022-2024, Nigeria's green logistics policies emphasized environmental protection, especially cutting greenhouse gases. As a nation hard-hit by climate change, Nigeria ramped up CO2 reduction efforts to honor its COP26 commitments. The government, party, and agencies prioritized sustainable initiatives like green logistics, issuing supportive laws and policies to create an enabling framework.

A 2023 Nigerian Logistics Report survey revealed strong interest in green practices among logistics providers and users. Analyses showed the sector remains embryonic, with growing demand for sustainability. Highlights included green logistics' positive effects on Southeast manufacturers' sustainability, via energy-efficient transport and eco-packaging. Despite congestion and pollution, integration with SDGs is gaining traction. Globally, SAP reported 70% of logistics leaders prioritizing sustainability, with 70% investing in low-carbon transport tech. Europe's SSCM index led at 85%, North America's at 70%; large firms held 71.73% of the 2023 green logistics market share, pioneering EVs and automated warehouses.

In Morocco, just 16.88% of logistics firms had formal emission-reduction systems, signaling regional gaps (Agyabeng-Mensah et al., 2019). Overall, the industry lags in full decarbonization but shows promising momentum. This underscores green logistics' role in Nigeria's long-term sustainability. Consumer awareness has surged, boosting demand for eco-friendly products and services. As supply chain endpoints, shifting preferences drive corporate adoption. By 2025, Nigeria's green logistics boomed post-fuel subsidy removal (May 29, 2023, via presidential address), fueled by the Electric Vehicle and Motorbike Transition Bill, tech focus, >30% consumer backing for green vehicles/fuels, and >10% willingness to pay premiums. Challenges like costs and awareness linger, but benefits in efficiency and environment spur uptake in optimized routing and packaging. Capacity building, infrastructure, and policy cohesion are critical, per the 2023 Report.

Resource shortages hinder Nigeria's logistics. The 2022 Nigerian Logistics Report rated financial capacity highest (4.24/5) for green adoption. With 98% SMEs in 2023, funding limits equipment upgrades and process overhauls. Skilled labor gaps exacerbate issues; the Nigerian Institute of Transport Technology (2025) forecasts a 1.5 million worker shortfall by 2030, needing 200,000 certified pros fluent in languages like Chinese, accelerating AI/automation.

dNigeria's logistics contributes 6.57-6.91% to GDP but trails developed peers in sustainability. Unlike Ghana, Egypt, and South Africa's mature EV fleets and emissions tracking, Nigeria lags due to fragmented infrastructure, weak incentives, and enforcement. Yet, its youthful digital talent, e-commerce rise, and P-CNG Strategy enable scalable green innovation—highlighting this study's urgency for actionable strategies.

External barriers include poor infrastructure: unreliable roads/ports, flawed planning, insecurity, corruption, low efficiency, peak-hour congestion, system desync, and minimal IT use. Government rules aid green logistics, but implementation falters from overlapping duties,

transportation bias (neglecting warehousing/IT), and gaps in recycling, packaging, and renewables.

Logistics fuels Nigeria's growth amid industrialization/urbanization, demanding eco-efficient chains. Hurdles like infrastructure, costs, and regulations persist, but tech like blockchain, IoT, AI, and automation cuts waste, boosts fuel efficiency, and enables tracking—enhancing performance (Oladele, 2021). Green logistics is essential for industry sustainability, yielding customers, revenue, cost savings, and competitiveness amid global green import/export standards. "Greening" is now mandatory for global supply chains. This study identifies key green logistics factors and proposes policies for Nigerian firms.

Conceptual Framework

Integrating Green SCOR with Technology Transfer Mechanisms

The proposed conceptual framework systematically integrates the six foundational management processes of the SCOR (Supply Chain Operations Reference) model which includes *Plan, Source, Make, Deliver, Return,* and *Enable* with critical technology transfer (TT) mechanisms that drive innovation across the supply chain. These TT mechanisms encompass a comprehensive spectrum of knowledge and technology acquisition channels, including in-house Research and Development (R&D) initiatives, strategic partnerships with universities and research centers, specialized consulting services, procurement of innovative products from third-party vendors, and the direct purchase of ready-to-deploy technologies. This multifaceted approach ensures that organizations can access cutting-edge solutions tailored to their green transformation needs.

A distinctive feature of this framework is the strategic incorporation of green factors into the traditional SCOR model architecture. This "greening" process systematically embeds environmental sustainability considerations into each of the six core processes, creating a holistic Green SCOR extension. Notably, this green-enhanced version was first formally introduced in the fifth iteration of the SCOR model. As articulated by Fatorachian and Kazemi (2025), Green SCOR represents a sophisticated evolution that methodically integrates environmental performance metrics, processes, and industry best practices directly into supply chain management operations. This integration extends across the entire product life cycle, systematically accounting for operational impacts from raw material extraction through final disposal (Li et al., 2023).

GSCM and the Triple Bottom Line Sustainability Paradigm

Green Supply Chain Management (GSCM) transcends mere environmental compliance; it fundamentally embeds ecological philosophy into core business strategies while simultaneously ensuring the long-term sustainable growth and viability of industrial ecosystems (Sun et al., 2025). Comprehensive sustainability evaluation within GSCM encompasses not only environmental dimensions but also critical ethical considerations and social responsibility imperatives (Ahmad et al., 2023; Liu et al., 2024).

At its core, the framework adopts the widely recognized Triple Bottom Line (TBL) perspective, which meticulously delineates and balances three interdependent performance dimensions: economic prosperity, environmental stewardship, and social equity. True organizational sustainability emerges at the strategic intersection where all three dimensions achieve optimal performance simultaneously (Ndiaye & Madani, 2020). Consequently, forward-thinking organizations must pursue excellence across all TBL pillars rather than optimizing any single dimension in isolation.

The seven principal GSCM determinants are Green Marketing, Green Design, Green Purchasing, Green Manufacturing, Green Distribution, Green Reverse Logistics, and Green Management System, they exhibit complex interdependencies that form a sophisticated analytical network structure. These elements interact dynamically, creating synergistic effects that amplify overall system performance and sustainability outcomes.

Detailed Process Mapping: Green SCOR Implementation

Plan: Strategic Green Foundation

Effective green planning forms the bedrock of SCOR operations, encompassing comprehensive environmental training programs, ISO 14001 environmental management system orientations, detailed sustainable action planning, eco-conscious product development strategies, and demonstrable employee commitment to environmental protection initiatives (Xie, 2024). Within the Plan phase, Green Marketing and Green Design emerge as pivotal components.

Green Marketing strategically leverages environmental positioning in product promotion, service delivery, and brand communications to appeal to eco-conscious consumers. Complementing this, Green Design represents a paradigm shift from traditional methodologies, delivering superior cost efficiencies while substantially reducing environmental footprints through optimized material use, energy-efficient processes, and lifecycle impact minimization (Wang & Yang, 2022).

Source: Sustainable Procurement Excellence

Zheng et al. (2025) define Sustainable Purchases/Green Purchasing as the strategic procurement of goods and services that demonstrate demonstrably lower environmental impacts compared to conventional alternatives serving identical functional requirements. This process extends beyond product selection to encompass rigorous ecological vetting of supply chain partners, ensuring alignment with comprehensive sustainability guidelines (Liu et al., 2023).

Make: Clean Production Innovation

Following sustainable sourcing, manufacturers must prioritize dual objectives: clean production processes and sustainable product outputs. Achieving these ambitions demands comprehensive innovation across organizational structures, production processes,

manufacturing technologies, and supply chain actor capabilities. Green Manufacturing specifically emphasizes part count minimization, material rationalization, component reuse strategies, and closed-loop systems, all contributing to dramatically more efficient product builds with reduced resource consumption and waste generation (Phi Nga & Phan Thanh, 2025).

Deliver: Green Logistics Optimization

The Deliver phase transitions into Green Distribution/Green Logistics, focusing on environmentally optimized transportation and delivery systems. Critical to success, customers must actively participate as conscious stakeholders, extending green strategies beyond organizational boundaries into consumption patterns (Return phase preparation).

Return: Closed-Loop Reverse Logistics

Post-consumption, the Return phase activates comprehensive Reverse Logistics systems to manage product returns, damaged goods, non-conforming items, packaging waste, and residual materials. This stage operationalizes the 3R framework (Reduce, Reuse, Recycle) alongside advanced waste management protocols. Strategic waste handling generates substantial cost savings, enhances competitive positioning, and creates value through reverse logistics optimization and industrial waste exchange ecosystems (Zou et al., 2015).

Enable: Green Management System Integration

Orchestrating the entire GSCM lifecycle requires sophisticated Planning capabilities and robust Green Management Systems (Enable). These systems provide strategic oversight of corporate environmental performance through executive leadership commitment, comprehensive policy frameworks, and organization-wide environmental engagement protocols (Musa et al., 2025). GSCM effectiveness hinges on multi-stakeholder collaboration extending beyond immediate suppliers to encompass customers, strategic partners, and internal management teams.

Technology Transfer Dynamics Across the Supply Chain

Technology Transfer (TT) permeates every SCOR process phase, facilitating knowledge and innovation flows both between supply chain actors and within individual organizations. This continuous TT enables the development of novel techniques and strategies specifically targeting effective environmental impact management. The framework features bidirectional flows of critical resources information, specialized knowledge, physical materials, and financial capital that interconnect all supply chain stages seamlessly.

To maximize supply chain efficiency, participating organizations must collaboratively manage logistics flows, inventory storage, and related activities—or strategically delegate these functions to specialized partners possessing comparative advantages. Optimal product

flows emerge from precisely coordinated production schedules, logistics operations, marketing strategies, and ancillary support activities (Musa et al., 2025).

Rabiu et al. (2024) underscore the paramount importance of information flows including real-time order status updates, delivery tracking, and performance metrics for achieving business success. Information Technology (IT) infrastructure serves as the backbone, enabling seamless communication across the extended supply chain network. Resource flows encompass both financial dimensions (payment systems, credit arrangements, ownership transfer protocols) and non-financial elements (human capital deployment, equipment utilization), collectively amplifying supply chain effectiveness and resilience.

Technology Transfer Impacts on Supply Chain Performance and Green Innovation Dynamics

The effectiveness of Technology Transfer (TT) on enhancing supply chain (SC) performance hinges fundamentally on the strategic types and methods employed for knowledge dissemination. When novel information permeates every node-spanning supplier, manufacturers, distributors, retailers, and end consumers, and also, the SC achieves heightened efficiency and operational efficacy. This seamless penetration accelerates information velocity, minimizes latency in decision-making, reduces redundancies, and fosters real-time responsiveness to market dynamics and disruptions.

The Imperative of Innovation in GSCM Adoption

Implementing Green Supply Chain Management (GSCM) demands transformative innovation as its foundational prerequisite. Green and sustainable innovation can be rigorously defined as the deliberate introduction or modification of processes, techniques, practices, systems, and products explicitly engineered to minimize social harms and environmental degradation. Core manifestations include advanced recycling protocols, sophisticated waste management architectures, enhanced green operational efficiency, and pioneering green design methodologies all converging to substantially diminish the ecological and societal footprints of organizational outputs.

These innovation facets must be holistically integrated into broader organizational sustainability strategies. Empirical evidence consistently demonstrates that breakthrough innovations flourish under the synergistic support of dedicated Research and Development (R&D) ecosystems and robust TT mechanisms. The innovation-to-GSCM pathway unfolds across five distinct, sequential phases, systematically adapted from the foundational frameworks of Hsu (2024) ATTC model and Zou et al. (2015).

Phase 1: Knowledge Acquisition – Building the Intellectual Foundation

The inaugural phase centers on **Knowledge**, representing the systematic accumulation of specialized expertise essential for mastering GSCM principles, operational practices, and their intertwined environmental-economic implications. Critical TT mechanisms operationalized

here include strategic collaborations with universities and research institutions, in-house R&D initiatives, patent licensing and protection strategies, and formalized knowledge-sharing platforms. For instance, joint academic-industry consortia might develop sector-specific GSCM toolkits, while patent pools enable rapid access to proven green technologies.

Phase 2: Decision Gate – Overcoming Adoption Barriers

The second phase, **Decision**, constitutes the pivotal evaluation juncture where organizations render definitive judgments on innovation adoption or rejection. Successful progression demands dismantling multifaceted barriers, with resistance to change emerging as the most formidable obstacle. This manifests as entrenched cultural inertia, fear of operational disruptions, perceived financial risks, and skepticism regarding ROI timelines. Mitigation strategies encompass change management training, pilot demonstrations yielding quantifiable "quick wins," and executive sponsorship to signal organizational commitment.

Phase 3: Development – Operationalizing the Innovation

Development, the third phase, grapples with the practical challenges of translating conceptual innovations into operational realities. This encompasses resolving technical integration issues, redesigning workflows, upskilling personnel, and establishing performance monitoring systems. Organizational complexities arise from legacy system incompatibilities, cross-departmental coordination gaps, and scaling challenges from pilot to enterprise-wide deployment.

Phase 4: Dissemination – Catalyzing Awareness and Adoption

The fourth phase, **Dissemination**, strategically amplifies innovation visibility to accelerate voluntary adoption across the extended enterprise. Multifaceted strategies include targeted awareness campaigns, comprehensive knowledge-building workshops, and strategic distribution of implementation materials (toolkits, case studies, best-practice guides). TT mechanisms dominate here through intensive training programs and specialized consulting engagements, equipping stakeholders with actionable implementation roadmaps.

Phase 5: Implementation – Institutionalizing Sustainable Practices

Culminating in the fifth phase, **Implementation** represents the most complex and dynamic stage: seamlessly embedding practical innovations into daily organizational routines. This requires sustained change reinforcement, continuous performance optimization, and adaptive governance structures to navigate emergent challenges.

Taxonomy of Sustainable Innovation Types in GSCM

As articulated by Karimi et al. (2023) and Ye & Zhang (2025), sustainable innovation encompasses the strategic introduction of novel or substantially enhanced products, production processes, management paradigms, business methodologies, and marketing

approaches delivering concurrent economic viability, social benefits, and environmental gains. This framework delineates five interdependent innovation categories essential for GSCM maturity:

- **Process Innovation**: Targets production methodologies for goods and services, prioritizing eco-efficiency gains. Distinguished manifestations include end-of-pipe pollution controls and cleaner production technologies that fundamentally reconfigure resource utilization patterns. Advanced implementations leverage closed-loop production systems and industrial symbiosis networks, dramatically enhancing enterprise-wide ecological performance.
- **Organizational Innovation**: Encompasses structural realignments, novel management philosophies, and formalized governance systems such as ISO 14001-certified Environmental Management Systems (EMS). These innovations cultivate adaptive cultures, cross-functional green teams, and performance-based sustainability incentives.
- **Product Innovation**: Drives the evolution or creation of environmentally superior products and services. Eco-design principles yield offerings featuring sustainable materials, extended durability, and minimized energy consumption profiles. Disruptive examples include renewable energy technologies and biodegradable packaging solutions representing entirely new product categories.
- **Marketing Innovation**: Revolutionizes customer engagement through environmentally resonant promotional strategies. By cultivating green brand equity, eco-labeling authenticity, and sustainability storytelling, these innovations stimulate premium pricing tolerance and loyalty among environmentally conscious consumer segments.
- **Business Model Innovation**: Catalyzes industry-wide transformation through three synergistic archetypes *industry model innovation* (redefining sector value chains), *revenue model innovation* (green premium pricing, circular economy leasing), and *enterprise model innovation* (servitization, platform ecosystems). Integrated deployment across these dimensions forges resilient, future-proof Green Supply Chains.

TT as the Continuous Thread Through GSCM Innovation

TT constitutes the indispensable connective tissue permeating every phase of the GSCM innovation lifecycle—from Knowledge inception through Implementation completion. As a multidimensional, intentional diffusion mechanism, TT systematically accelerates innovation adoption velocity while mitigating implementation risks (Zou et al., 2015). This comprehensive process orchestrates diverse stakeholders—including internal champions, external partners, and regulatory bodies—through coordinated activities encompassing knowledge translation, pilot validation, and scalable deployment.

Effective TT architecture must be purposefully engineered to catalyze rapid innovation diffusion, creating network effects that compound GSCM benefits across participating ecosystems. The bidirectional, multi-flow nature of TT ensures that learning from implementation feeds back into knowledge repositories, perpetuating a virtuous cycle of continuous green innovation.

Research Methodology

This research adopts an exploratory and conceptual design, employing a hybrid analytical approach that integrates systematic literature synthesis, contextual situation analysis of Nigeria's logistics sector, and decision-making modeling via the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, as adapted from Hsu's (2024) two-stage KTT-GSCM Multicriteria Model. The study is not experimental but framework-oriented, identifying interrelationships among green supply chain management (GSCM), knowledge/technology transfer (KTT), and innovation to propose policy recommendations for sustainable logistics in Nigeria.

Data Sources

Data were primarily secondary, systematically gathered from peer-reviewed literature on KTT, GSCM, and innovation (e.g., Scopus/Google Scholar sources from 2020-2025), industry reports (e.g., 2023 Nigerian Logistics Association Report; 2022 Nigerian Logistics Report), policy documents (e.g., COP26 commitments; Electric Vehicle and Motorbike Transition Bill), and official statistics (e.g., World Bank port data; Nigerian Institute of Transport Technology forecasts; Ministry of Transport fleet statistics). These enabled identification of global green logistics trends, successful cases from developing nations (e.g., China, EU benchmarks), and Nigeria-specific challenges such as infrastructure deficits, low smart tech adoption (20% per Nigeria Chamber of Commerce), SME funding barriers (80% per SMEDAN), and managerial awareness gaps (60% misunderstanding carbon neutrality per Nigerian Environmental Protection Organization).

Analytical Scope and Contextualization

The geographical scope focuses on Nigeria's logistics sector, with emphasis on major hubs (Lagos ports, Kano/Abuja northern routes, Port Harcourt) and nationwide challenges like port inefficiencies and EV infrastructure gaps.

Analysis and Framework Validation

Systematic review built the Green SCOR-TT conceptual framework; DEMATEL validated interdependencies; and scenario analysis derived recommendations (e.g., carbon targets by 2030, regional hubs in Lagos/Kano). Triangulation across sources confirmed themes like infrastructure as the primary barrier, ensuring replicable policy insights for Nigeria and similar contexts.

Results and Discussion

Analysis of Survey Results: Key Challenges Facing Green Logistics in Nigeria

Inadequate Infrastructure

Persistent Road, Port, and Rail Deficiencies: Despite substantial government investments, Nigeria's transportation infrastructure remains suboptimal. Traffic congestion and deteriorating road conditions continue to hamper logistics efficiency, particularly in urban centers, ports, and key highways nationwide.

- **Port Inefficiency Example**: World Bank data reveals Nigerian ports process 20-foot containers in over 2 days versus 1.5 days in Asian counterparts (Hui et al., 2023). Ranked 183rd/185 globally (2024 CPPI), ports suffer from corruption, bureaucracy, outdated infrastructure, manual operations, and congestion diverting cargo to Ghana while slowing economic growth despite Lekki Deep Sea Port upgrades. NITT reports stress needs for automation, connectivity, and regulatory reform, as delays spike energy use and emissions.

Critical EV Charging Infrastructure Gap: Electric vehicles represent a prime solution for logistics decarbonization, yet Nigeria lacks sufficient charging networks, concentrated only in major cities while bypassing logistics hubs and corridors.

- **Data Point**: Nigeria hosted just 200 operational stations in 2022 (Ministry of Industry and Trade), versus hundreds of thousands in China/EU (Zou et al., 2015), underscoring massive infrastructure deficits.

Limited Adoption of Clean Energy Fleets: High costs, short battery life, and charging scarcity suppress electric/clean energy vehicle uptake despite global momentum.

- **Statistics**: Nigerian CNG/electric trucks comprised <1% of fleets in 2023 (Ministry of Transport), contrasting Germany's >20% (Nguyen et al., 2024).

Low Penetration of Smart Logistics Technologies

IoT, AI, and big data could transform efficiency and cut energy use, yet Nigerian logistics firms lag with manual operations dominating.

- **Survey Data**: Only <20% utilize smart systems (Nigeria Chamber of Commerce) versus >50% in EU/USA (Liu & Guo, 2023).

Weak Policy Framework and Incentives

While Nigeria commits to global emission targets, logistics-specific carbon reduction policies remain absent, with regulations targeting manufacturing/energy instead.

- **Global Benchmarks**: EU's Green Deal and US Clean Energy Act provide explicit low-carbon guidance (Hsu, 2024).

Financial and Technical Constraints

SME Funding Shortfalls: Large firms possess capital for green tech, but SMEs struggle with transition costs.

- **Findings**: >80% of SMEs cite funding barriers preventing advanced green tech adoption, eroding competitiveness (SMEDAN survey, Oladele, 2022).

Absence of Technology Transfer Platforms: Firms lack channels for international tech access despite recognizing smart/green tech importance.

- **Comparative Success**: China/EU leverage TT platforms for EV/intelligent transport deployment, yielding substantial emission cuts (Ahmad et al., 2023).

Limited Social Awareness

Insufficient Environmental Consciousness: Public and corporate focus prioritizes short-term costs over long-term sustainability.

- **Survey Results**: 60% of logistics managers misunderstand carbon neutrality objectives, dampening green tech enthusiasm (Nigerian Environmental Protection Organization, Ngo, 2022).

Table 1: Overview of the main issues and challenges of green logistics in Nigeria

Challenge Category	Description	Supporting Data/Case
Inadequate Infrastructure	Road congestion slows logistics; insufficient EV charging; inefficient port operations	Port handling >2 days/container; only ~500 charging stations nationwide
Technology Adoption Lags	Minimal electric vehicle use; limited smart tech deployment	<1% electric vans in fleets; just 15% use smart logistics systems
Imperfect Policy Framework	Abundant policies but lacking emission reduction guidance	Nigeria produces policies but lacks logistics-specific targets; EU has established frameworks
Funding & Technical Bottlenecks	SMEs lack capital; no technology transfer channels	80% SMEs unable to adopt green tech; China/EU succeed via TT platforms
Weak Social Awareness	Limited environmental consciousness among stakeholders	60% of managers misunderstand carbon neutrality goals

Short-Term Strategy (1-2 Years): Infrastructure and Policy Framework

Promote the establishment of policies and regulations Establish carbon reduction policies and targets:

- **Establish Clear Emission Reduction Targets**

The Nigerian government should adopt ambitious, time-bound carbon reduction goals aligned with global benchmarks and local needs, such as achieving 40% emissions cuts in the logistics

sector by 2030. This requires implementing carbon pricing mechanisms (taxes and cap-and-trade systems) alongside comprehensive regulatory guidelines.
Global Benchmark: EU Climate Act mandates ≥55% reduction by 2030 (Liu et al., 2023).

Enact the Low Carbon Transport Act
Urgently introduce comprehensive:

- **Low Carbon Transport Legislation** mandating phased transition from fossil fuel vehicles. Require all logistics firms to replace conventional fleets with electric vehicles (EVs) or alternative clean energy options within 5-10 years.

Accelerate Green Infrastructure Development

- **Prioritize EV Charging Networks**: Deploy charging stations and renewable energy refueling infrastructure across major cities, logistics corridors, and industrial hubs to enable widespread electric truck adoption.
- **International Example**: China surpassed 1 million charging piles by 2023 (Hsu et al., 2024).

Transform Logistics Warehouses

- Provide incentives for warehouse retrofitting with solar panels, wind turbines, and smart energy management systems to meet storage facility power demands sustainably.
- **Success Case**: Amazon's German green warehouses utilize solar/wind power combined with intelligent systems for optimal energy efficiency (Zou, 2015).

Table 2: Short-term (1-2 years) strategies and infrastructure construction to promote green logistics in Nigeria

Short-term Strategy		
Focus Area	**Content**	**Specific Actions**
Drive Policies & Regulations	Carbon reduction policies and targets	Set 30% emissions reduction target by 2030; implement carbon tax and cap-and-trade system
	Low-carbon transport law	Mandate phase-out of fuel vehicles; require transition to electric/clean energy vehicles
Infrastructure Development	Green logistics infrastructure	Build EV charging stations in major cities and logistics hubs
	Warehouse energy retrofit	Promote renewable energy adoption for storage facility power needs

Medium-Term Strategy (2028-2030): Technology Application & Regional Cooperation: Accelerate Technology Deployment
Comprehensive EV Fleet Rollout: Prioritize full adoption of electric trucks and clean energy vehicles across major logistics corridors. Implement targeted subsidy programs and purchase

incentives to facilitate gradual replacement of fossil fuel fleets, slashing emissions while boosting global competitiveness.

- **Case Study**: US firms UPS and FedEx achieved substantial emission cuts by transitioning to electric/hydrogen fleets, simultaneously lowering long-term operating costs through tech innovation.

End-to-End Digital Logistics Management:

- Deploy IoT, big data, and AI for real-time transportation tracking, route optimization, and inventory control—eliminating empty runs, minimizing energy waste, and enhancing supply chain transparency/traceability.
- **Example**: China's JD Logistics reduced emissions >30% via intelligent distribution and automated warehousing.

Develop Regional Green Logistics Hubs

Strategic Hub Construction: Transform key cities (Lagos, Abuja, Kano, Kaduna, Port Harcourt) into national green logistics centers featuring sustainable warehousing, low-carbon transport networks, and renewable energy infrastructure—serving as efficient gateways for domestic/international trade.

- **Global Benchmark**: Netherlands' Port of Rotterdam leads as a renewable-energy-powered hub with cutting-edge electric/hydrogen logistics infrastructure.

Strengthen Regulatory Oversight

National Carbon Monitoring System: Deploy IoT/big data platforms for real-time tracking of logistics firms' emissions, with regular public reporting of reduction targets.

- **EU Model**: Comprehensive carbon regulatory framework enables cross-border trading based on emission allowances, driving reductions via market incentives.
- **Launch Carbon Trading Market**: Introduce emissions trading system allowing firms to buy/sell carbon credits, lowering abatement costs through market mechanisms while attracting green investments.

Table 3: Medium-term (3-5 years) strategy for the low-carbon transition of Nigeria's logistics industry: Technology application and regional cooperation.

Policy Category	Specific Measures	Cases/Comparisons
Technology Application	**EV Fleet Promotion**: Deploy electric trucks on major routes with subsidies/preferential policies to cut emissions & boost competitiveness	UPS/FedEx successfully transitioned fleets to electric/hydrogen vehicles
	Digital Management: Implement IoT, big data, AI for	JD Logistics achieved 30% emission cuts via full digitalization

Policy Category	Specific Measures	Cases/Comparisons
	transport monitoring, route optimization & efficiency gains	
Regional Cooperation	**Green Logistics Hubs**: Develop sustainable warehousing & renewable energy infrastructure in Abuja, Kaduna, Kano, Lagos, Port Harcourt	Port of Rotterdam: Global leader in renewable-powered, automated logistics
Regulatory Strengthening	**Carbon Emission Regulation**: National monitoring system using data analytics for real-time emissions tracking	EU's comprehensive carbon regulatory framework enables trading
	Carbon Trading Market: Launch emissions trading to lower abatement costs & attract green investments	Market-based incentives driving EU low-carbon transformation

Long-Term Strategy (2031-2035): Zero-Carbon Logistics & Global Competitiveness

Achieve Complete Zero-Carbon Logistics System

Full Decarbonization Mandate: Establish nationwide zero-carbon logistics infrastructure with all hubs, warehouses, and transport achieving net-zero emissions. Enact binding regulations requiring 100% electric/hydrogen vehicle fleets and full conversion of logistics facilities to renewable energy sources.

- **Domestic Example**: Dangote Cement's 2060 carbon neutrality pledge includes CNG/electric fleet transition and green warehousing, progressively eliminating logistics emissions.

Deploy Hydrogen Energy & Cutting-Edge Technologies

Hydrogen Logistics Leadership: Accelerate hydrogen adoption for heavy-duty trucks and long-haul routes through substantial infrastructure investments and international R&D partnerships, achieving complete industry decarbonization.

- **Global Benchmark**: Japan collaborates with Germany/Korea on hydrogen truck commercialization via joint technical investment and cooperation.

Elevate Nigeria's Global Green Logistics Competitiveness

International Green Product Promotion: Position Nigerian green logistics services in global markets through strategic trade agreements with EU, North America, and ASEAN, exporting low-carbon solutions and attracting multinational supply chains.

- **Model**: EU Green Supply Chain Initiative incentivizes MNC participation via favorable trade policies and market access.

Deepen Global Cooperation & Innovation Leadership

Strategic International Partnerships: Lead in global logistics standards while accessing advanced technologies through alliances with EU, US, and Asian nations. Join initiatives like the EU-Japan "Green Logistics Technology Alliance" focusing on EV, hydrogen, and intelligent systems.

Table 4: Long-term (5-10 years) development strategy of Nigeria's logistics industry: Achieving zero-carbon goals and enhancing global competitiveness

Tactics	Specific Measures	Cases/Comparisons
Zero-Carbon Logistics	**Complete zero-carbon system**: 100% electric/hydrogen vehicle fleets + fully renewable-powered storage facilities	Amazon's 2040 carbon neutrality target
	Hydrogen technology deployment: Hydrogen solutions for heavy-duty trucks & long-haul transport	Japan-Germany-Korea hydrogen energy collaboration
International Competitiveness	**Global green product promotion**: Green trade agreements with EU & partners to export low-carbon logistics services	EU Green Supply Chain Initiative driving green product sales
International Cooperation	**Deepen global partnerships**: Shape international logistics standards + lead green innovation projects	EU-Japan "Green Logistics Technology Alliance" joint R&D

Conclusions and Recommendations

As global pressure to cut carbon emissions intensifies, Nigeria's logistics sector must embrace a green transformation as an unavoidable path forward. Over the coming decade, the country will encounter intense competition from both local and international markets, yet it will also unlock substantial growth prospects. Through enhancements in infrastructure, cutting-edge technologies, and refined policies, Nigeria can emerge as a key contender in the worldwide green logistics arena.

Advancing green logistics enables Nigeria to slash emissions from its logistics operations while boosting supply chain performance, lowering costs, and drawing in foreign capital alongside global partnerships directly supporting UN Sustainable Development Goals 9 (Industry, Innovation, and Infrastructure) and 13 (Climate Action). This shift will generate numerous employment opportunities and elevate living standards, balancing economic expansion with environmental stewardship. For enduring sustainable progress, Nigeria should sustain a forward-looking global perspective, positioning green logistics as its central strategy. By leveraging technological advancements, robust policies, and worldwide collaboration, the nation can fully green its logistics industry, establishing a strong foothold in the global green economy and securing lasting competitive edges internationally.

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