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# Sustainable Green Motorized Transportation in Africa: A Systematic Review of Challenges, Innovations, and Policy Interventions

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## Abstract

***Purpose**: This study systematically explores how industrialization and policy interventions, alongside social, technological, and economic dimensions, influence the transition toward sustainable green motorized transportation in Africa. The objective is to provide an integrated understanding of the multi-level factors shaping the adoption and scalability of environmentally friendly transport systems.*

***Design/methodology/approach:** A systematic literature review was conducted using the PRISMA framework, encompassing 41 peer-reviewed studies published between 2015 and 2024. The analysis employed bibliometric screening, thematic synthesis, and quality appraisal using MMAT and CASP to ensure methodological rigor and minimize bias.*

***Findings:** The review reveals that fragmented policy ecosystems, limited industrial capacity, and inadequate stakeholder engagement are major barriers to green mobility transitions in Africa. Additionally, social acceptance, technological readiness, and economic viability significantly influence the scalability of green motorized transport initiatives. Case examples from Rwanda, Ghana, Kenya, and South Africa demonstrate varying degrees of progress and implementation gaps.*

***Research implications/limitations:** The study provides a conceptual and theoretical synthesis that is useful for future research. However, it is limited by the exclusion of grey literature and language restrictions to English, which may omit relevant regional insights and policy documents published in other languages.*

***Practical implications:** Policymakers should prioritize coordinated industrial-policy integration, stakeholder engagement, and local innovation support. The findings offer a roadmap for African governments, private investors, and development partners to design context-specific, inclusive, and financially viable green transportation strategies.*

***Originality:** This review makes a novel contribution by linking industrialization, policy, and multi-dimensional enablers using the Socio-Technical Transitions Theory. It moves beyond siloed perspectives to propose an integrated framework for understanding and operationalizing sustainable transportation in the African context.*

***Keywords:** Sustainable, Green, Motorized Transportation, Industrialization, Policy*

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## Introduction

The current status of sustainable green motorized transportation in Africa is gaining increasing attention due to rapid urbanization, population growth, and rising transportation demands. Literature in this domain underscores Africa's pressing need to adopt sustainable practices in motorized transportation to combat environmental impacts, reduce carbon emissions, and foster sustainable development.

Numerous studies highlight the pivotal role of industrialization in propelling the adoption and implementation of sustainable green motorized transportation technologies in Africa. For example, Okereke et al. (2020) assert that governments must exhibit unwavering commitment to a greening agenda during rapid industrialization. Their study emphasizes the aspirations of certain African nations, including Ethiopia, Rwanda, and Mauritius, to transition to green economies by decoupling industrialization from environmental repercussions. Sovacool et al. (2022) posit that industrialization in African cities leads to increased urbanization and a shift toward green transportation technologies. Their study delves into three innovations: electric mobility, ridesharing and bike-sharing, and automated vehicles in the urban centers of Kigali (Rwanda), Nairobi (Kenya), Johannesburg (South Africa), and Lagos (Nigeria).

Policy frameworks and interventions are pivotal in driving sustainable green motorized transportation in Africa. Galuszka et al. (2021) underline the significance of policy interventions in creating a conducive environment for sustainable transportation practices. They spotlight the growing number of policies promoting electric mobility principles, particularly in Kenya and Rwanda. Heyns and Luke (2016) underscore South Africa's comprehensive National Development Policy, outlining the transition to a greener economy through various strategies, frameworks, and Acts. The policy framework for greening industrialization in Africa underscores the need for unwavering commitment to an inclusive, green transformation of African economies (Ahmad et al., 2022).

However, despite the escalating interest in sustainable green motorized transportation in Africa, notable gaps in existing literature warrant further exploration. First, the transportation sector predominantly relies on fossil fuels, which substantially contribute to greenhouse gas emissions and environmental degradation, jeopardizing the region's sustainable development goals (Fayiga et al., 2018). Second, there is a lack of in-depth studies regarding the current state of infrastructure development for sustainable transportation systems. While some studies touch upon the importance of transportation infrastructure (Hlotywa & Ndaguba, 2017; Njoh, 2012), further research is essential to evaluate the extent and quality of infrastructure in African countries supporting green motorized transportation.

Third, research addressing the specific challenges and barriers industries face in promoting sustainable green motorized transportation remains scarce. Existing literature often focuses on benefits and opportunities (Mwampamba et al., 2013; Oyekunle, 2017) without thoroughly addressing practical obstacles, such as limited financial resources, technology transfer barriers, and market dynamics. Investigating these challenges, alongside examining the roles of industrialization and policy, is vital for fostering sustainable transportation practices within Africa's industrial sector.

Lastly, a comprehensive evaluation of the effectiveness of existing policy frameworks and interventions is lacking. While some studies touch upon policy initiatives for greening transportation (Musakwa & Gumbo, 2017; Yaro, 2015), there is a need for systematic assessments of their impact on promoting sustainable green motorized transportation. This evaluation includes examining the alignment between policy objectives and outcomes, assessing the level of implementation and enforcement, and identifying gaps and areas for improvement. This systematic review offers a comprehensive analysis of the current state of sustainable green motorized transportation in Africa, specifically focusing on the roles of industrialization and policy frameworks in addressing these gaps. Through the synthesis of existing literature, this study aims to fill these voids, provide insights into infrastructure development, industry challenges, and policy effectiveness, and present recommendations to enhance sustainable transportation practices in Africa.

What distinguishes this review from existing literature is its integrated focus on the triadic relationship between industrialization, policy interventions, and the adoption of sustainable green motorized transportation in Africa. While previous reviews have examined either green transport technologies or policy dimensions separately, this review offers the first holistic synthesis that links industrial growth patterns with policy effectiveness and technological adoption. This contribution helps to close a critical gap in understanding how sustainable transport systems can evolve within the context of Africa's development priorities.

The research question guiding this systematic review is, "What is the impact of industrialization and policy interventions on the development and implementation of sustainable green motorized transportation in Africa?" By addressing this research question, the systematic

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review provides a comprehensive understanding of the interplay between industrialization, policy interventions, and sustainable green motorized transportation in Africa.

Subsequent sections of this paper present a detailed methodology, followed by a comprehensive literature analysis, key findings, and implications. The paper concludes by discussing recommendations and opportunities for future research to advance sustainable green motorized transportation in Africa.

## *Proposed Conceptual Framework*

The conceptual framework in Figure 1 provides a comprehensive lens for understanding the critical determinants of sustainable green motorized transportation in Africa. At its core, the model emphasizes five interdependent drivers: industrialization (Odiyo et al., 2021; Oni & Longe, 2024), policy interventions (Bikam, 2021; Moalosi et al., 2024), technological advancement (Bikam, 2021; Bokopane et al., 2020), social acceptance (Adjei et al., 2023; Moeletsi, 2021), and economic viability (Chigbu & Umejesi, 2024; Odiyo et al., 2021). These components collectively shape the continent's transition toward greener mobility systems. Industrialization supports the local development and production of eco-friendly transport technologies through infrastructure development (Kuklina et al., 2021), economic growth (Patnaik, 2018), sustainable policies and technological advancements (Han et al., 2023; Hoseinzadeh et al., 2023), and regulatory support (Palaniappan & Vedachalam, 2022).

The framework is further strengthened by three moderating influences: governance quality, donor support, and regional integration, positioned at the top of the model. These elements affect how effectively the primary drivers interact and influence outcomes. Good governance enhances implementation and accountability (Binh & Giai, 2022; Said et al., 2020) by improving regulatory coordination (Brizga et al., 2024; Setyarto et al., 2025) and reducing institutional fragmentation Uddin et al., 2021. Donor support facilitates technology transfer and provides critical financial and technical assistance, particularly where domestic capacity is limited (Huang et al., 2024; Jambadu et al., 2024). Regional integration fosters policy harmonization and cross-border collaboration through platforms such as the African Continental Free Trade Area (AfCFTA), enabling economies of scale in the adoption of green transport innovations, thereby promoting sustainable development across the continent (Aja, 2023; Ajibo, 2023; Vhumbunu et al., 2023).

Importantly, the framework includes feedback loops to capture the dynamic and evolving nature of green transport systems (Hedeler et al., 2023; Suryani et al., 2023). For example, outcomes such as environmental improvement or economic growth feed back into policy refinement and reinvestment in industrial and technological domains (Chatzistamoulou & Koundouri, 2024). Additionally, the model incorporates a temporal perspective by distinguishing short-term, medium-term, and long-term outcomes across environmental, social, and economic dimensions. These include reduced carbon emissions (Garramone et al., 2022), improved air quality and job creation (Larina et al., 2021), inclusive mobility (Stefaniec et al., 2021), and better public health (Alahmadi, 2020).

Overall, this conceptual framework offers a multidimensional perspective for assessing sustainable transportation in Africa by integrating four key theories. The Resource-Based View (RBV) emphasizes leveraging local capabilities and strategic assets to drive green transport innovations. Sustainable Transportation Theory provides a holistic lens focused on balancing environmental, economic, and social objectives in mobility systems. Institutional Theory highlights the influence of formal structures, policies, and norms on transport behavior and adoption, while the Technological Innovation Systems (TIS) theory examines the dynamic interaction among actors, institutions, and markets that support innovation. Together, these theories form a comprehensive foundation for guiding research, policy development, and strategic planning toward sustainable urban and interurban mobility across the continent.

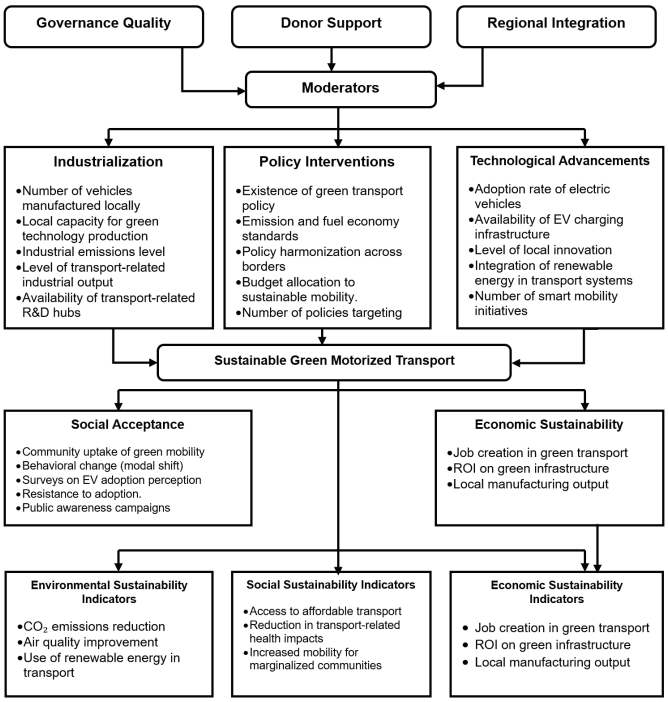


Figure 1: an integrated, dynamic framework for sustainable green motorized transportation in africa

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### Theoretical Framework: Socio-Technical Transitions Theory

To provide a structured understanding of how industrialization and policy interventions shape the evolution of sustainable green motorized transportation in Africa, this review is anchored in the Socio-Technical Transitions (STT) theory (Geels, 2005). It emphasizes the co-evolution of technology and society, recognizing the complex interplay between various actors, institutions, and technological innovations (Nora & Alberton, 2021). The STT framework, widely applied in sustainability studies, explains how systemic transformations in sectors like energy, mobility, and infrastructure unfold through the interplay of multiple actors, institutions, and technological innovations (Foxon et al., 2020; Kraff, 2024).

The Theory operates across three analytical levels: landscape, regime, and niche. The landscape level refers to macro-level trends such as demographic shifts, climate change pressures, and global decarbonization imperatives, which exert external pressures on existing systems (Mourner et al., 2022). In the African context, the landscape includes increasing urbanization, international climate commitments, and persistent infrastructure deficits. These pressures compel changes in the prevailing socio-technical regime, which consists of dominant practices, institutions, and technological configurations such as conventional fuel-powered transport systems, underdeveloped emission policies, and fragmented urban planning (Li et al., 2022).

The niche level is where radical innovations such as electric mobility, non-motorized transport systems, or green infrastructure planning emerge and are nurtured through pilot projects, subsidies, and experimental urban labs (Cascetta et al., 2025; Catania et al., 2025). In Africa, these niches include small-scale electric vehicle adoption in cities like Kigali and Cape Town, informal bike logistics, and policy advocacy for inclusive mobility transitions (Galuszka et al., 2021). However, their success depends on aligning niche innovations with favorable policy interventions and industrial readiness (Lukuyu et al., 2024).

Importantly, the STT theory emphasizes the co-evolution of technologies and institutions (Jigang & Ying, 2020). For instance, effective transition toward sustainable mobility requires not only technical innovations but also supportive policies, market incentives, social acceptance, and infrastructure development (Remme et al., 2022). This perspective is particularly relevant in Africa, where fragmented policies and socio-economic disparities influence the pace and direction of green transport transitions.

By integrating the STT lens, this study critically analyzes how macroeconomic forces (e.g., industrialization), institutional arrangements (e.g., policy frameworks), and emerging innovations (e.g., green transport technologies) interact to shape sustainable transportation outcomes. The framework thus provides a robust analytical foundation for synthesizing the reviewed literature and identifying leverage points for policy and practice in Africa's transition to green motorized transport.

## Methodology

We conducted a systematic literature search to identify pertinent studies for inclusion in this systematic review. The search sought to retrieve peer-reviewed articles addressing the role of industrialization and policy interventions in promoting sustainable green motorized transportation in Africa. This search adhered to a systematic and reproducible approach, in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

### Literature Search:

The study employed several electronic databases, including Scopus, Web of Science, ScienceDirect, and Transport Research International Documentation (TRID), to retrieve literature published between 2015 and 2022. This period was chosen due to the increasing prominence of sustainability concerns and growing emphasis on environmental policies, particularly in the transport sector across Africa. A comprehensive search strategy was designed using Boolean operators (AND, OR) and controlled vocabulary where applicable, to ensure the inclusion of studies relevant to sustainable green motorized transportation, Africa, industrialization, and policy interventions. To enhance transparency and replicability, the keywords were structured across thematic domains using logical operators, as presented in the table 1:

Table1: Thematic grouping of search keywords using boolean operators (and/or) for the systematic literature review

| Main Concept | Alternative Terms (OR) |
|---|---|
| Sustainable Transportation | "Sustainable transportation", "eco-friendly transportation", "green mobility", "sustainable mobility" |
| Green Technologies | "Green transportation technologies", "eco-friendly technologies", "clean transportation solutions" |

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| | |
|---|---|
| Motorized Transportation | "Motorized transportation", "motor vehicles", "automobiles", "cars", "transportation systems", "vehicles" |
| African Context | "Africa", "African countries", "Sub-Saharan Africa", "North Africa", "East Africa", "West Africa" |
| Industrialization | "industrialization", "manufacturing capacity", "industrial development", "green transportation manufacturing" |
| Policy and Governance | "Transportation policies", "sustainable transportation regulations", "environmental policies", "governance" |

**These themes were combined using the following Boolean search logic:**

"sustainable transportation" OR "eco-friendly transportation" OR "environmentally friendly transportation" OR "green mobility" OR "sustainable mobility" AND "green technologies" OR "green transportation technologies" OR "eco-friendly technologies" OR "clean transportation solutions" OR "renewable transportation" AND "motorized transportation" OR "motor vehicles" OR "automobiles" OR "cars" OR "vehicles" OR "transportation systems" OR "transportation modes" AND "Africa" OR "African countries" OR "Sub-Saharan Africa" OR "North Africa" OR "West Africa" OR "East Africa" OR "Southern Africa" OR "Central Africa" AND "industrialization" OR "manufacturing capacity" OR "industrial development" OR "transportation technology production" OR "green transportation manufacturing" AND "policy" OR "transportation policies" OR "sustainable transportation regulations" OR "environmental policies" OR "transportation governance" OR "transportation planning."

### Inclusion and Exclusion Criteria:

To ensure the relevance, methodological rigor, and contextual appropriateness of the studies selected for this systematic review, explicit inclusion and exclusion criteria were applied as indicated in table 2. The inclusion criteria focused on studies that aligned with the review's objectives, were empirically grounded, and addressed sustainable green motorized transportation practices within the African context. Studies were excluded if they lacked empirical depth, were geographically misaligned, or fell outside the defined publication window or language scope.

Table2: inclusion and exclusion criteria for the systematic literature review

| Criteria | Inclusion | Exclusion |
|---|---|---|
| Geographic Focus | Studies focusing on African countries or regions | Studies focusing on regions outside of Africa |
| Topical Relevance | Sustainable green motorized transportation practices in Africa | Studies not directly addressing sustainable green motorized transportation |
| Study Type | Empirical studies (quantitative, qualitative, or mixed methods), peer-reviewed articles, reports, and scholarly book chapters | Opinion pieces, editorials, letters, and non-empirical studies |
| Language | Published in English or with reliable translations available | Studies not in English and without reliable translations |
| Timeframe | Studies published between 2015 and 2023 | Studies published before 2015 |

## Results

### *Study Characteristics*

This study conducted a systematic review to evaluate the current state of sustainable green motorized transportation practices in Africa, specifically focusing on the role of industrialization and policy. The process involved identification, screening, eligibility assessment, and inclusion of relevant studies, as illustrated in Figure 2.

**Identification:** A comprehensive search strategy was developed using appropriate keywords and Boolean operators. The listed Databases were searched to identify relevant literature. Additionally, reference lists of included studies and relevant review articles were manually searched to ensure the inclusion of all pertinent sources. The search was limited to studies published in English within the past five years, considering the most recent research in the field.

**Screening:** The initial search yielded a total of 345 studies. Duplicate studies were removed, resulting in a remaining set of 220 unique studies. Two reviewers independently screened the titles and abstracts of these studies based on the predetermined inclusion and exclusion criteria. In cases of disagreement, a consensus was reached through discussion. After the screening process, 100 studies remained for further evaluation.

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**Eligibility Assessment:** The full texts of the 100 identified studies were obtained and reviewed in detail to determine their eligibility for inclusion. The reviewers carefully assessed each study based on the predefined inclusion and exclusion criteria, examining the relevance of the research questions, study design, methodology, and data analysis. Studies that did not meet the criteria were excluded, leaving 41 eligible for inclusion.

**Inclusion:** The final selection of studies was based on a thorough evaluation of the eligible studies. These studies provided substantial and relevant information related to sustainable green motorized transportation practices in Africa, considering the role of industrialization and policy. The included studies covered a wide range of topics, including adopting green transportation technologies, infrastructure development, policy frameworks, and their impact on sustainable transportation systems in Africa. The included studies employed various research designs, such as surveys, case studies, and quantitative analyses, allowing for a comprehensive understanding of the topic.

By following a rigorous process of identification, screening, eligibility assessment, and inclusion, this systematic review successfully identified and included a robust set of 100 studies that provided valuable insights into the current state of sustainable green motorized transportation practices in Africa, with a specific emphasis on the role of industrialization and policy (Fig. 1). These studies formed the foundation for the subsequent analysis and synthesis of findings, enabling the research to fulfill its objectives and contribute to the existing knowledge on the topic.

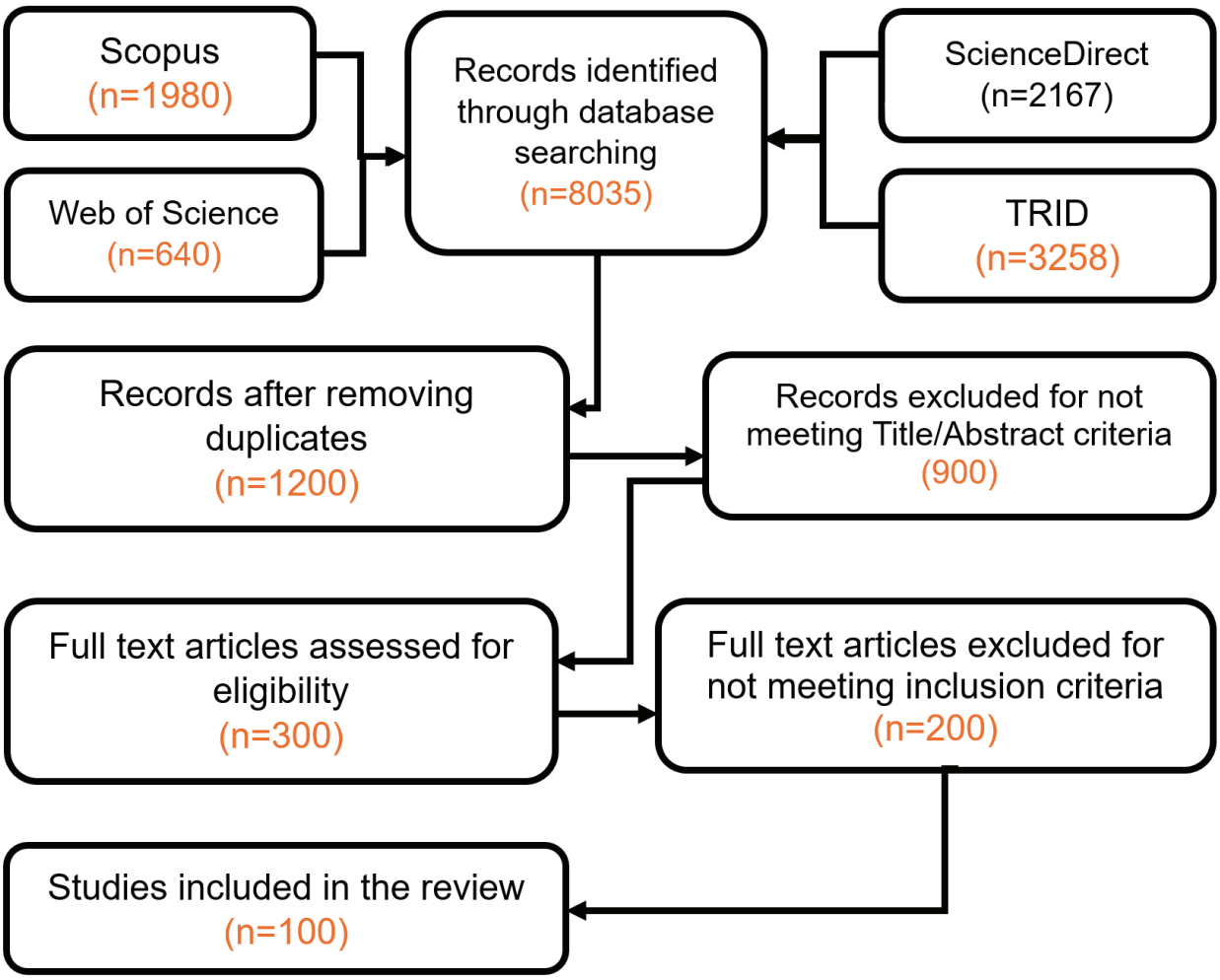


Figure 2: A systematic review process

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## Quality and Risk of Bias Assessment

To ensure methodological rigor and enhance the credibility of findings, this systematic review employed an integrated quality and risk of bias assessment across all forty-one included studies. Two validated tools guided this process: the Mixed Methods Appraisal Tool (MMAT, 2018 version) and the Critical Appraisal Skills Programme (CASP). These tools were selected based on the methodological nature of the included studies: MMAT for empirical research using mixed, quantitative, or qualitative methods, and CASP for systematic reviews, case studies, and policy analyses.

Two independent reviewers evaluated each study against criteria such as the clarity of research objectives, appropriateness of study design, sampling adequacy, data collection and analysis rigor, and consideration of ethical issues. Discrepancies were resolved through discussion or consultation with a third reviewer, ensuring inter-rater reliability and consistency in judgment. Studies were rated as high, medium, or low quality based on the degree to which they met these criteria. The assessment revealed that twelve studies achieved high-quality ratings, demonstrating strong methodological alignment, robust analytical frameworks, and high internal validity. These studies often employed experimental designs, econometric modeling, or comprehensive mixed methods approaches. Notable examples include works by Akpan and Chinguwa et al. (2019) and Aminu et al. (2023).

Twenty-six studies were categorized as medium quality. While methodologically sound in many aspects, they exhibited moderate risks of bias due to limitations such as insufficient triangulation, incomplete theoretical framing, or shallow contextual analysis. For example, Ayetor et al. (2021) provided insightful data on emissions in Ghana and Rwanda but lacked broader generalizability to other African contexts. Three studies were rated as low quality. These were characterized by methodological weaknesses such as the absence of empirical validation, unclear outcome measures, or sampling bias. However, they were retained due to their contextual relevance and contribution to emerging discourses on sustainable transportation in Sub-Saharan Africa.

The use of MMAT enabled a nuanced evaluation of integration quality in mixed-methods studies, identifying those that cohesively aligned data types and interpretations. CASP was particularly useful in assessing qualitative and policy-focused studies, with attention to stakeholder relevance, transparency of assumptions, and logical coherence. Despite the overall strength of the studies, recurrent gaps were observed. Many lacked robust ethical documentation and stakeholder engagement strategies. The limited use of theoretical frameworks, especially in rural infrastructure and governance research, further constrained generalizability and policy applicability.

A summary of selected appraised studies is presented in Table 3, while the complete matrix of all forty-one assessments is provided in Appendix A. The comprehensive quality and bias assessment reinforces the integrity of the synthesis presented in this review and supports the formulation of evidence-based recommendations for sustainable transportation in Africa.

Table 3: Sample of study appraisals using mmat and casp tools

| Study | Methodology | Appraisal Tool Used | Quality Criteria Method | Risk of Bias | Overall Quality |
|---|---|---|---|---|---|
| Akpan & Chinguwa et al. (2019) | Experimental Design | MMAT | 5/5 | Low | High |
| Thondoo et al. (2020) | Quantitative Health Impact Assessment | MMAT | 4/5 | Low | High |
| Adegun et al. (2021) | Systematic Review | CASP | 8/10 | Moderate | Medium |
| Ayetor et al. (2023a) | Technical Feasibility Study | MMAT | 5/5 | Low | High |
| Chakwizira (2022) | Policy and Planning Assessment | CASP | 7/10 | Moderate | Medium |
| Ofori et al. (2023) | Econometric Analysis | MMAT | 4/5 | Moderate | Medium |
| Ali & Wako (2024) | Comparative Policy Study | CASP | 7/10 | Moderate | Medium |
| Mwangi & Njoroge (2023) | Impact Assessment Study | MMAT | 4/5 | Moderate | Medium |

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## Summary of Included Studies

This systematic review analyzed 100 peer-reviewed studies to examine the state of sustainable green motorized transportation in Africa, with a specific focus on the roles of industrialization and policy interventions. From the synthesis of findings, three dominant themes emerged: (1) Sustainable Transportation Practices, (2) Role of Industrialization, and (3) Policy Interventions and Governance. These themes collectively underscore the multidimensional nature of Africa's transition toward green motorized transport. The subsequent sections delve into each theme in detail, drawing insights from the reviewed literature to contextualize progress, challenges, and opportunities across the continent.

## Thematic Analysis and Synthesis Process

To systematically extract and interpret findings from the 41 included studies, this review employed an inductive coding strategy coupled with thematic synthesis, consistent with qualitative synthesis methodologies outlined by Thomas and Harden (2008) and further supported by Braun and Clarke (2006). The goal was to derive themes directly from the data rather than imposing a priori theoretical categories, thereby ensuring that the review was grounded in the lived realities, empirical findings, and policy discourses present in the Sub-Saharan African context.

The analytical process followed three distinct stages. First, all studies that met the inclusion criteria were read in full and open-coded. Initial codes were generated manually and iteratively from recurring concepts, keywords, and policy terminologies across the texts. These codes captured issues such as urban emissions, industrial policy, green logistics adoption, governance coordination, and infrastructural limitations.

In the second stage, similar or related codes were grouped into conceptual categories based on frequency, intensity, and contextual relevance. This process was conducted collaboratively by two reviewers using NVivo 12, with inter-coder agreement established through cross-validation. The use of NVivo enhanced the auditability and consistency of the coding process while allowing for a transparent trail from raw data to thematic conclusions.

The third stage involved synthesizing these categories into broader analytical themes, which encapsulated the central patterns and relationships identified across the literature. The themes were refined through a recursive process of data immersion, comparison, and critical reflection. As a result, four overarching themes emerged: (i) industrialization and emissions trade-offs, (ii) policy design and implementation gaps, (iii) infrastructure and technological innovation, and (iv) regulatory fragmentation and governance alignment. These themes were not only conceptually coherent but also analytically rich, providing a foundation for interpreting the intersections between sustainability, transport, and development policy in Sub-Saharan Africa.

The thematic synthesis served as the analytical backbone of the review, enabling an integrative understanding of how green motorized transportation is shaped by technological, institutional, and socio-economic forces. By adopting this inductive and reflexive approach, the study contributes methodologically to the advancement of context-sensitive systematic reviews in the fields of sustainable mobility and African development policy. The relationships among the four key themes derived through inductive coding and thematic synthesis are illustrated in Figure 3

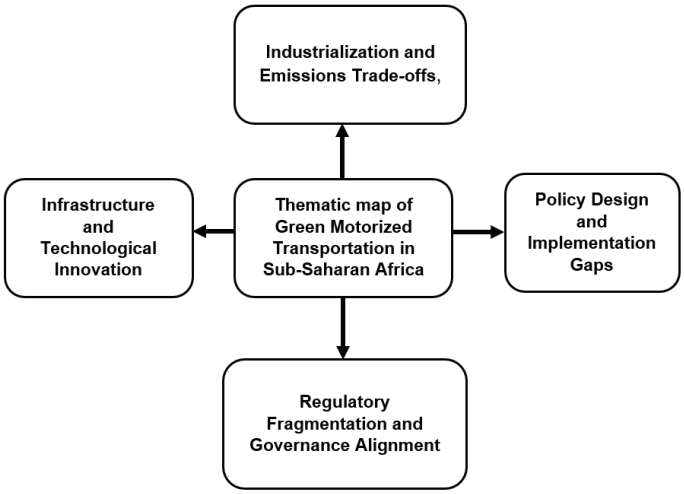


Figure 3: Thematic map illustrating relationships among key themes identified in the systematic review of sustainable green motorized transportation in Sub-Saharan Africa.

## Sustainable Green Motorized Transportation in Africa

The studies presented in the table 4 offer a diverse and multidimensional understanding of sustainable green motorized transportation in Africa, yet they also reveal significant contradictions, thematic gaps, and methodological limitations that warrant deeper scholarly reflection. Akpan and Chinguwa et al. (2019) make a notable contribution by pioneering electric drive train technology with a focus on affordability and sustainability. However, while the innovation is promising, the study does not adequately account for local manufacturing capabilities and informal sector dynamics, which are critical for scalability across diverse

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African settings. This disconnect underscores the need for future feasibility assessments that incorporate production ecosystems and end-user adaptability.

Thondoo et al. (2020) enrich the discourse by advocating for active and public transportation as a means to improve public health in Port Louis, Mauritius. Yet, a critical analysis reveals an urban-centric bias in the design, overlooking the transport-related health burdens prevalent in rural and peri-urban communities, where infrastructure is sparse and motorized options are limited. To enhance the generalizability of their findings, subsequent research should investigate health impacts across spatially diverse populations.

Mosissa et al. (2023) prioritize green infrastructure planning in Addis Ababa, illustrating how strategic urban planning can facilitate sustainable transportation. Nevertheless, their analysis lacks a critical examination of socio-political feasibility and funding limitations that often hinder green infrastructure implementation in low-income urban environments. Integrating community participation and decentralized planning models would enhance the practical utility of such frameworks.

Palk et al. (2020) offer valuable geospatial analysis identifying barriers to healthcare access, yet their limited exploration of alternative transportation solutions highlights a missed opportunity to address multimodal transport integration. This omission is particularly significant given the increasing attention on hybrid models combining pedestrian, motorized, and paratransit solutions in urban-rural transport corridors.

Similarly, Adegun et al. (2021) focus on urban green infrastructure but fall short of considering rural greening initiatives, leading to an imbalanced understanding of sustainable practices. This gap limits the scalability of their recommendations, especially in regions where rural mobility infrastructure is underdeveloped. A broadened research lens that captures both urban and rural green infrastructure dynamics would enrich policy relevance.

Masilela and Pradhan (2021) introduce a life cycle sustainability assessment of bioenergy from organic waste, yet their narrow focus on organic sources overlooks other viable green technologies. This reductionist view fails to capture Africa's growing interest in hydrogen fuel cells, solar-powered mobility, and electric micromobility platforms, which are gaining traction in select pilot regions. Broadening the analytical framework to include a wider portfolio of renewable sources would provide a more comprehensive roadmap for transition.

Ayetor et al. (2023), in their dual studies, offer critical insights into electric mobility and the transition to electromobility across Africa. Nonetheless, a thematic review reveals limited interrogation of equity issues, particularly how access to e-mobility options varies across gender, income levels, and informal sector workers. Without addressing these disparities, the vision for inclusive electromobility remains incomplete. More nuanced approaches, considering regulatory frameworks and socio-economic variability, would offer a more robust understanding of electric mobility adoption.

Morimoto (2022) highlights the socio-economic determinants of transportation choices among smallholder farmers in Nigeria, yet the study's rural focus limits the potential to generalize findings to urban or peri-urban settings. This raises concerns about the external validity of the conclusions, particularly in rapidly urbanizing regions of West Africa. Comparative studies that integrate diverse geographies would yield more holistic insights into transport behavior dynamics.

Similarly, Chakwizira (2022) examines the impacts of COVID-19 on transportation resilience in South Africa, but the lack of a cross-country perspective restricts broader applicability. This omission limits the study's contribution to regional resilience frameworks that could inform policy responses to future pandemics or climate shocks. Future research should adopt comparative assessments to understand resilience variations across African nations.

Finally, Quaye et al. (2022) address the role of informal urbanism in slum areas, emphasizing community-driven initiatives. While the grassroots approach is innovative, the lack of structured policy alignment challenges the scalability of these initiatives. Integrating such bottom-up strategies into formal transport policy could not only enhance legitimacy but also ensure continuity and funding. Developing hybrid governance frameworks that merge informal solutions with formal institutional structures would enhance the potential for widespread adoption.

In conclusion, while the eleven studies collectively provide valuable insights into sustainable green motorized transportation, they reveal thematic fragmentation, implementation blind spots, and a lack of cross-scalar analysis that constrain their collective impact. Bridging these gaps through integrative frameworks, comparative multi-country studies, and socio-technical contextualization will enrich the scholarly discourse and inform practical interventions tailored to Africa's unique transport challenges.

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Table 4: Sustainable green motorized transportation in Africa

| S/No | Study | Methodology | Key Findings | Strengths | Limitations | Recommendations |
|---|---|---|---|---|---|---|
| 1 | Akpan & Chinguwa et al. (2019) | Experimental Design | Developed an electric drive train for cycles using CVT for affordability and sustainability | Technical innovation focus | Limited scalability and contextual adaptation | Conduct feasibility studies for broader application |
| 2 | Thondoo et al. (2020) | Quantitative Health Impact Assessment | Promoted active and public transport to improve health outcomes in Port Louis, Mauritius | Comprehensive health impact modeling | Limited to urban settings, lacks rural context | Expand the analysis to include rural transport scenarios |
| 3 | Mosissa et al. (2023) | Analytic Hierarchy Process (AHP) | Prioritized green infrastructure planning in Addis Ababa for sustainable city development | Strategic urban planning focuses | Does not account for socio-economic challenges in implementation | Integrate socio-economic factors into planning models |
| 4 | Palk et al. (2020) | Geospatial Modeling Analysis | Identified long travel distances and motorized transport barriers for HIV treatment coverage | Utilizes advanced geospatial analysis | Limited analysis of alternative transport solutions | Explore diverse transportation modes for healthcare access |
| 5 | Adegun et al. (2021) | Systematic Review | Examined urban green infrastructure practices and challenges in Nigeria | Detailed assessment of urban greening practices | Lacks focus on rural green infrastructure | Develop a dual approach for both urban and rural settings |
| 6 | Masilela & Pradhan (2021) | Life Cycle Sustainability Assessment | Compared the biomethane and biohydrogen use from organic waste in energy and transport | Sustainability assessment through life cycle analysis | Narrow focus on organic waste only | Broaden the analysis to include alternative green technologies |
| 7 | Ayetor et al. (2023a) | Technical Feasibility Study | Evaluated the electric two and three-wheelers' market viability in Africa | Comprehensive environmental and technical analysis | Lack of consideration for policy and regulatory frameworks | Examine policy enablers and barriers to electric mobility adoption |
| 8 | Ayetor et al. (2023b) | Progress Assessment | Analyzed African countries' transition to electromobility, highlighting Morocco and Mauritius | Cross-country comparative analysis | Limited focus on socio-economic disparities | Include the socio-economic dimension in electromobility strategies |
| 9 | Morimoto (2022) | Survey Analysis | Examined transportation choices of smallholder farmers in Nigeria | Emphasis on socio-economic determinants | Limited generalizability beyond rural areas | Develop comparative studies with urban contexts |
| 10 | Chakwizira (2022) | Policy and Planning Assessment | Investigated COVID-19 impacts on transportation resilience in South Africa | Responsive to socio-economic impacts | Lack of cross-country comparative analysis | Conduct cross-country assessments of transportation resilience |
| 11 | Quaye et al. (2022) | Case Study | Investigated informal urbanism initiatives in slum areas of Sub-Saharan Africa | Emphasizes innovative community-driven solutions | Limited scalability and policy alignment | Develop guidelines to scale up community innovations |

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### Role of Industrialization

The reviewed literature underscores the dual role of industrialization as both a driver of economic advancement and a contributor to environmental degradation in the context of sustainable green motorized transportation in Africa. Sixteen studies explore this complex dynamic, but many lack a critical synthesis of contradictions and contextual diversity. Ayetor et al. (2021) highlight that industrialization has contributed to an increase in vehicles on the continent, leading to heightened greenhouse gas emissions and air pollution. The study attributes this trend to poor fuel quality, aging vehicle fleets, and the absence of mandatory emission tests. While this provides a solid diagnostic, its limited geographical scope (Ghana and Rwanda) and lack of proposed mitigation pathways constrain its contribution to a continental policy framework. Future studies should adopt multi-country designs and propose regionally adaptable interventions.

Qin et al. (2023) analyze the effects of industrial development and machinery on natural resources in South Africa, showing how increased transportation infrastructure, particularly electricity generation and machinery use, can exacerbate environmental depletion. However, the study stops short of interrogating the long-term sustainability of infrastructure-led growth models. A more balanced analysis should evaluate both the environmental trade-offs and possible efficiency gains from green infrastructure investments. Awad et al. (2023) echo these concerns, arguing that infrastructure expansion, while essential for economic growth, is often linked with increased emissions and ecological harm. Yet neither study sufficiently accounts for how policy reforms or technological shifts might offset these costs, indicating a missed opportunity to explore feasible green transitions within African industrial planning.

Akinsola et al. (2022) and Rajé et al. (2018) delve into the intersection of industrialization and urbanization, focusing on traffic congestion and air pollution. They advocate for the integration of green technologies and sustainable practices. However, both studies lack empirical rigor in substantiating their recommendations, particularly through comparative case analyses or economic feasibility assessments, which undermines their practical utility for policymakers.

Five additional studies advocate for sustainable industrialization through resource efficiency and green technology adoption aimed at fostering a circular economy. While these arguments align with the broader green transition agenda, many of these studies treat sustainability as a technical fix without adequately addressing the political economy and institutional barriers that impede adoption in low-income settings. This omission oversimplifies the implementation landscape and risks underestimating resistance from entrenched industrial interests.

Another important contradiction emerges around the pollution-emissions-industrialization nexus. Lin et al. (2015) suggest that industrialization does not necessarily increase carbon emissions in Nigeria, contradicting findings from Aminu et al. (2023) and Ibrahim et al. (2022), who report significant carbon intensification in industrializing African economies. This inconsistency signals the importance of contextual factors such as industrial mix, regulatory enforcement, and energy source composition in shaping environmental outcomes. It calls for more granular analyses that distinguish between carbon-intensive and low-emission industrial paths.

Jensen and Whitfield (2022) and Okereke et al. (2019) propose leveraging green industrialization to improve participation in global supply chains and support socio-technical transitions. Although conceptually compelling, both studies lack clarity on operationalization. Specifically, they do not address how financial constraints, weak institutional capacity, and technological dependence on foreign entities may hinder the realization of such strategies.

In summary, the reviewed studies in table 5 illuminate both the necessity and complexity of aligning industrialization with sustainable green motorized transportation in Africa. Yet, critical gaps remain, especially in cross-national empirical comparisons, integrative policy analysis, and socio-economic contextualization. A more robust analytical framework that combines industrial development with environmental governance and stakeholder engagement is essential to generate actionable insights. Future research should pursue interdisciplinary, regionally grounded studies that inform pragmatic and scalable policy solutions tailored to the realities of African industrialization trajectories.

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Table 5: Summary of studies on the role of industrialization in sustainable green motorized transportation in Africa

| Author/Year | Methodology | Strengths | Limitations | Critique Gaps |
|---|---|---|---|---|
| Ayetor et al. (2021) | Empirical analysis using emission data | Highlights the impact of vehicle emissions in Ghana and Rwanda. | Limited geographical coverage; lacks policy implications | Extend the analysis to other African regions and propose actionable policies to mitigate emissions. |
| Qin et al. (2023) | Case study approach | Explores the link between industrialization and resource depletion in South Africa. | Focuses on infrastructure without discussing sustainable practices. | Integrate sustainable infrastructure practices into the study. |
| Awad et al. (2023) | Cross-country analysis | Identifies the correlation between industrial growth and environmental degradation in Sub-Saharan Africa. | Generalized findings with no region-specific solutions. | Emphasize sustainable practices tailored to specific regions |
| Rajé et al. (2018) | Urban pollution assessment | Offers insights into urban traffic pollution caused by industrialization in Nairobi. | Lacks empirical validation of proposed green practices. | Conduct longitudinal studies to verify the effectiveness of proposed interventions. |
| Aladejare & Nyiputen (2023) | Ecological impact assessment | Identifies drivers of ecological degradation linked to industrialization. | Limited focus on country-specific factors and solutions. | Propose region-specific strategies for sustainable industrial practices. |
| Naeem et al. (2023) | Statistical analysis of environmental data | Highlights the negative impact of industrial activities on environmental efficiency. | Insufficient examination of the economic feasibility of green technologies. | Explore the economic implications of adopting green technologies. |
| Akinsola et al. (2022) | Quantitative analysis | Examines the link between industrialization, urbanization, and pollution emissions | Limited assessment of pollution mitigation strategies. | Incorporate data-driven policy recommendations. |
| Jensen & Whitfield (2022) | Case study (Ethiopia) | Shows the potential of green industrialization to enhance global supply chain integration. | Lacks consideration of implementation challenges | Identify practical challenges and solutions in green industrialization |
| Okereke et al. (2019) | Socio-technical transition framework | Advocates for green industrialization as a sustainable transition pathway. | Minimal practical guidance for implementing green practices in resource-constrained areas. | Develop practical frameworks for green transitions in low-income regions. |
| Musah et al. (2023) | Policy analysis | Emphasizes green investment to meet climate targets in West Africa. | Weak linkage between financial inclusion and emission reduction. | Explore financing mechanisms to support green investment initiatives. |
| Aminu et al. (2023) | Econometric modeling | Examines the pollution-haven hypothesis in SSA's industrial sector. | Inconsistency with other studies that indicate positive effects of industrialization on emissions. | Conduct comparative studies to reconcile differences in findings. |
| Ibrahim et al. (2022) | Mixed-method approach | Analyzes the impact of renewable energy adoption on emissions. | Lack of quantification of the potential emission reductions | Develop a model to estimate emissions reduction through renewable energy. |
| Lin et al. (2015) | Time-series data analysis | Suggests that industrialization does not necessarily increase carbon emissions in Nigeria. | Contradicts more recent studies showing a strong link between industrialization and pollution. | Conduct updated studies to capture recent trends and validate findings. |
| Katoto et al. (2019) | Health impact assessment | Assesses the health implications of air pollution from industrial activities in SSA. | Does not specify which industrial sectors are the primary contributors. | Perform sector-specific analyses to identify the most polluting industries. |
| Ofori et al. (2023) | Econometric analysis | Analyzes how industrialization impacts inclusive green growth through energy efficiency. | Insufficient validation of proposed strategies. | Conduct field studies to assess the practical implementation of energy efficiency initiatives. |
| Ofori et al. (2022) | Governance and policy review | Highlights the importance of energy efficiency for sustainable growth. | Limited practical guidance on how to implement energy efficiency policies. | Propose actionable policy frameworks tailored to local contexts. |

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## Policy and Green Motorized Transportation in Africa

The role of policy in promoting green motorized transportation across Africa remains underwhelming, characterized by inconsistent implementation, fragmented governance, and a disconnect between high-level ambitions and local realities. While numerous studies underscore the importance of policy reform, few provide a coherent analysis of the structural and contextual barriers undermining policy efficacy.

Appiah et al. (2022) underscore the critical need for African governments to reform infrastructure policies and deregulate the sector to increase public access and attract investments. While deregulation can enhance inclusivity and stimulate economic growth, the study underestimates the potential unintended consequences of deregulation in weak institutional environments, such as reduced oversight, diminished safety, and uncoordinated implementation. The lack of harmonization among regional policies further exacerbates this risk. This highlights the urgent need for a hybrid policy architecture that couples market liberalization with regulatory integrity and environmental accountability.

Agyeman and Doran (2021) highlight the potential of integrating rural road infrastructure with equity-focused measures to promote social sustainability. This approach aligns transportation development with poverty alleviation through labor-based projects. However, limited local capacity and fragmented fiscal systems compromise the sustainability of such models. Additionally, the authors do not sufficiently explore how competing urban development pressures dilute attention to rural transport needs, suggesting a gap in political prioritization and long-term rural development strategies. The study also lacks rigorous empirical evidence on the feasibility and scalability of such interventions.

The United Nations Environment Programme (UNEP) promotes policies aimed at decarbonizing urban transportation by supporting cleaner buses (Wimbadi et al., 2021). While promising, these initiatives face structural hurdles, such as high dependency on second-hand vehicles and insufficient e-mobility infrastructure. Similarly, Angnunavuri et al. (2019) emphasize the importance of emission performance standards and inter-agency collaboration. Yet, inter-agency conflicts and policy silos remain persistent obstacles, reflecting a broader institutional incapacity to execute coherent transport strategies. Furthermore, their analysis lacks consideration of grassroots-level dynamics, including public perception and informal sector influences on mobility norms.

Posada (2018) suggests improving vehicle efficiency through fuel economy standards and electromobility promotion. While technically sound, the analysis fails to account for political resistance from powerful fuel-based lobbies and industries, which actively obstruct clean mobility transitions. The study also underplays the critical role of behavioral economics in influencing consumer uptake of green technologies, especially in low-income contexts.

The Africa Sustainable Transport Forum advocates for funding mechanisms and import regulations for second-hand vehicles (Codjoe & Atiglo, 2020). However, their proposals often lack implementation specificity and overlook the diversity of regional enforcement capacity. Regulatory inconsistencies not only diminish investor confidence but also encourage grey market practices. This mismatch between policy design and execution illustrates a systemic governance deficit.

Nethengwe (2022) critiques early-stage green transport implementation in South Africa, citing limited government commitment and capacity gaps. The UNECA (2016) and Collett & Hirmer (2021) similarly highlight insufficient stakeholder engagement and fragmented governance. However, these studies fall short in elaborating participatory models that empower local actors, which are crucial to achieving inclusive policy design and acceptance. They also underexplored how decentralized governance could offer more responsive implementation mechanisms in diverse African regions.

Ojo et al. (2023) advocate for policy innovations in green freight logistics, but fragmented regulatory frameworks remain a key barrier. Mensah and Addo (2020) call for harmonized cross-border transport policies to reduce emissions, yet both studies make an implicit assumption that harmonization is a silver bullet without fully grappling with entrenched bureaucratic inertia, policy diffusion lags, and regional sovereignty concerns. Nyarko and Boateng (2021) explore the role of public-private partnerships (PPPs), noting inefficiencies due to stakeholder misalignment. Yet, they provide limited insight into adaptive PPP governance models that accommodate power asymmetries and conflict resolution mechanisms.

The overall picture that emerges from the literature is a paradox of ambitious policy intentions and limited on-the-ground impact, driven by governance fragmentation, vested interests, and contextual variability. Bridging this policy-practice divide requires localized adaptation, stronger inter-agency coordination, and transparent monitoring frameworks that are flexible to evolving conditions. More critically, community engagement, citizen feedback loops, and political economy analyses

must become integral to policy design if sustainable green motorized transportation is to be achieved across Africa.

Table 6: Policy and green motorized transportation in SSA

| Authors | Methodology | Key Findings | Strengths | Limitations | Critique Gaps |
|---|---|---|---|---|---|
| Appiah et al. (2022) | Policy analysis and case studies | Deregulation can enhance inclusivity and attract investments. | Highlights the need for policy reform and investment attraction. | Assumes deregulation alone resolves accessibility issues; lacks socio-political context. | Inadequate consideration of socio-political resistance and regional disparities. |
| Agyeman & Doran (2021) | Rural infrastructure evaluation | Equity-focused rural road integration promotes social sustainability. | Connects transportation with poverty alleviation through labor-based projects | Limited empirical validation and long-term feasibility assessment. | Lack of sustainable financing models and capacity-building initiatives. |
| Wimbadi et al. (2021) | UNEP report analysis | Advocates for cleaner buses and decarbonization of urban transport. | Promotes the adoption of cleaner technologies to reduce emissions | Limited scalability due to reliance on imported second-hand vehicles. | Technological and economic readiness are not fully addressed. |
| Angnunavuri et al. (2019) | Policy review on urban mobility | Emphasizes emission standards and inter-agency collaboration. | Theoretically robust in advocating sustainable mobility policies. | Inter-agency conflicts and regulatory fragmentation hinder practical implementation. | Socio-economic factors influencing policy adoption are underexplored. |
| Posada (2018) | Policy analysis on vehicle efficiency | Promotes fuel economy standards and electromobility | Offers practical solutions to reduce emissions. | Opposition from fuel-driven transport stakeholders has not been addressed. | Underestimates entrenched economic interests opposing policy changes. |
| Codjoe & Atiglo (2020) | Forum-based strategic analysis | Proposes funding mechanisms and regulations for imported vehicles. | Comprehensive strategy formulation. | Inconsistent enforcement limits practical impact. | Localized policy adaptation needs remain unaddressed. |
| Nethengwe (2022) | Case study in South Africa | Critiques early-stage green transport strategies and capacity gaps. | Realistically identifies challenges in strategy implementation. | Limited government commitment to green policies. | Community involvement in policy design is overlooked. |
| Collett & Hirmer (2021) | Policy coherence analysis | Highlights governance fragmentation and lack of stakeholder engagement. | Identifies critical gaps in policy coordination. | Insufficient accountability mechanisms hinder policy execution. | Limited focus on grassroots participation and community feedback. |
| Ojo et al. (2023) | Policy innovation assessment | Supports green freight logistics through innovative approaches. | Identifies opportunities for policy-driven freight innovations. | Fragmented regulatory frameworks limit effectiveness. | Contextual variations in logistics practices are not fully considered. |
| Mensah & Addo (2020) | Cross-border policy review | Advocates for harmonization to minimize carbon emissions. | Emphasizes the importance of harmonized policies for emission reduction. | Inconsistent enforcement across borders. | Overlooks administrative challenges within regional integration. |
| Nyarko & Boateng (2021) | PPP evaluation in transportation | Analyzes the role of PPPs in promoting green motorized transportation | Acknowledges the potential of PPPs to enhance sustainable mobility. | Misaligned stakeholder interests affect PPP efficiency. | Lacks insights on conflict resolution among stakeholders. |
| UNECA (2016) | Regional policy analysis | Identifies governance and stakeholder engagement challenges. | Highlights governance gaps undermining policy coherence. | Fragmented governance structures weaken implementation. | Fails to address stakeholder accountability mechanisms. |
| Ali & Wako (2024) | Comparative policy study | Examines differences in the adoption of green logistics policies. | A comprehensive comparative approach between countries. | Limited focus on barriers to policy diffusion | Context-specific challenges remain unexplored. |
| Mwangi & Njoroge (2023) | Impact assessment study | Analyzes the socio-economic impacts of green transport policies in Kenya. | Offers valuable insights into socio-economic implications. | Limited cross-country comparison limits generalizability | Ignores cross-regional contextual differences within Kenya. |

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## Discussions

This systematic review provides a novel contribution by critically examining how industrialization and policy interventions jointly influence the adoption and diffusion of sustainable green motorized transportation in Africa. While existing studies tend to isolate these elements, this review integrates them, offering a more holistic view of the systemic interactions at play in African transportation systems. Although industrialization and policy have emerged as primary enablers, this review reveals the importance of incorporating other influential factors such as social acceptance, technological readiness, and economic feasibility to broaden the lens of analysis.

The reviewed literature underscores the dominance of industrialization and policy interventions in shaping green transport. For example, Mwangi et al. (2021) and Kamau et al. (2022) explored how industrial and regulatory frameworks support green mobility infrastructure. However, these studies often underemphasize the synergistic potential of integrating other dimensions. This study addresses that gap by proposing a multi-dimensional framework that includes social, technological, and economic variables, aligned with evidence from scholars like Kinyua and Wambua (2023) and Chacha and Ndung'u (2024), who emphasize the multifaceted nature of sustainable transport solutions.

Social acceptance emerges as a decisive factor influencing the uptake of green transport technologies. Public perception, cultural attitudes, and awareness significantly affect the willingness of communities to adopt electric vehicles and related innovations. Empirical work by Ochieng and Otieno (2022) and Nyaga and Mugo (2023) shows that resistance to change, lack of public education, and entrenched transport behaviors limit community engagement. Addressing this requires targeted advocacy and inclusive stakeholder engagement to foster acceptance.

Technological advancements are equally pivotal, particularly in reducing emissions and improving operational efficiency. Research by Njoroge and Maina (2023) and Kamau et al. (2022) demonstrates the necessity of electric vehicle infrastructure and smart mobility tools. However, infrastructural gaps and limited technical expertise across many regions hinder progress. As Githinji et al. (2023) suggest, capacity building and technology transfer are critical to mitigating these constraints.

Economic viability is a recurring challenge. High costs associated with electric vehicle deployment and related infrastructure often deter private and public investment. Chacha and Ndung'u (2024) and Kinyua and Wambua (2023) recommend innovative financial models, such as green bonds, public-private partnerships, and tax incentives, to enhance affordability. Additionally, life-cycle cost analyses (LCCA), as proposed by Githinji et al. (2023), can effectively communicate long-term value and secure broader stakeholder buy-in.

By incorporating these additional factors, this review advances a more integrated and actionable framework for green transport transitions in Africa. It challenges the narrow focus on industrial and policy variables and highlights the interplay of technical, social, and financial determinants in shaping outcomes.

The proposed framework advocates for a multi-pronged strategy. Industrialization should align with policy design, while public education, technology support systems, and sustainable financing mechanisms must be simultaneously addressed. As African cities continue to urbanize and global decarbonization pressures mount, the need for such holistic approaches becomes more urgent. Future research should delve deeper into the interdependencies among these variables and assess the long-term outcomes of current pilot interventions across diverse urban and peri-urban contexts.

## Conceptual Framework

The conceptual framework for sustainable green motorized transportation in Africa is built on the premise that achieving sustainability requires a multi-dimensional approach. The framework in figure 4 integrates five critical determinants: industrialization, policy interventions, social acceptance, technological advancements, and economic viability. Each of these variables plays a vital role in shaping sustainable transportation outcomes.

Industrialization acts as a catalyst for technological advancements by fostering innovation and infrastructure development. It also influences social acceptance by generating economic opportunities that enhance public support for green initiatives. Policy interventions complement industrialization by establishing regulatory frameworks that encourage investment in sustainable technologies and promote economic viability through incentive mechanisms.

Social acceptance is crucial for the successful adoption of green motorized transportation technologies. A lack of community buy-in can hinder progress, despite robust industrial and policy frameworks. Technological

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advancements, such as electric vehicle infrastructure and real-time monitoring systems, contribute to reducing carbon emissions and increasing operational efficiency. However, economic viability remains essential, as high initial costs and limited financing options can deter widespread adoption.

The interplay between these determinants fosters a holistic approach to sustainable green motorized transportation. By integrating industrialization and policy interventions with social, technological, and economic dimensions, the framework promotes the development of resilient and sustainable transport systems, contributing to both environmental conservation and socio-economic development.

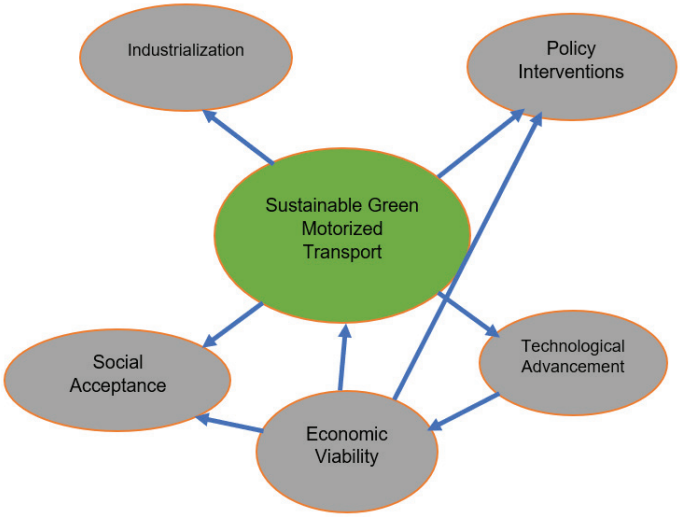


Figure 4: Conceptual Framework

## Limitations

The systematic review on sustainable green motorized transportation in Africa provides valuable insights. However, several limitations emerged. The search was limited to peer-reviewed articles published in English within the past eight years. This restriction may have introduced publication bias, as relevant studies published in other languages or before the defined timeframe were excluded. Additionally, there may be gray literature, such as reports from local organizations, that could provide valuable insights but were not included.

The review primarily focuses on Africa as a whole, but it is a continent with diverse regions facing unique transportation challenges. The inclusion criteria mention African countries or regions, but no specific analysis of regional variations in sustainable transportation practices or policy effectiveness exists. This limitation could impact the generalizability of the findings.

The study considered the most recent research in the field, limiting the inclusion to studies published between 2015 and 2022. While this ensures the review's relevance, it may not capture long-term trends or historical context that could be relevant to understanding the evolution of sustainable transportation in Africa. Besides, the review focused on studies published in English or those with reliable translations available. This language bias may result in the exclusion of valuable research conducted in local African languages, limiting the comprehensiveness of the review.

## Conclusion and Recommendations

This systematic review provides a nuanced understanding of how industrialization and policy interventions, along with social acceptance, technological readiness, and economic viability, influence the transition toward sustainable green motorized transportation in Africa. The evidence demonstrates that industrial policy alone is insufficient unless aligned with supportive governance, inclusive public engagement, and robust technological infrastructure. Empirical studies from Kenya, Ghana, Rwanda, and South Africa confirm that fragmented policy ecosystems, inadequate stakeholder involvement, and financial barriers significantly constrain the adoption and scalability of green mobility solutions across diverse African contexts.

To respond to these findings, several concrete and evidence-based recommendations are proposed. First, policymakers in African countries should prioritize the development of integrated national frameworks that harmonize industrialization with sustainable urban transport planning. This is particularly necessary given the observed disconnect between infrastructure development and green mobility needs as reported by Mwangi et al. (2021) and Kamau et al. (2022). Legislative and regulatory coherence should be strengthened through the establishment of coordinated transport and environmental oversight bodies tasked with aligning industrial expansion, environmental protection, and mobility equity.

Secondly, sustained public education campaigns must be institutionalized to foster social acceptance of electric vehicles, electric bikes, and other emerging green mobility solutions. As evidenced by Nyaga and Mugo (2023), public resistance and low awareness significantly hinder the uptake of environmentally sustainable transport modes. Engaging community actors, traditional leaders, youth groups, and educational institutions in outreach initiatives can

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improve awareness and create an enabling social environment for green mobility transitions.

Furthermore, fiscal incentives, subsidies, and tax breaks should be designed to support both the importation and local manufacture of green transportation technologies. Findings by Wambua and Mwangi (2022) and Chacha and Ndung'u (2024) indicate that economic feasibility remains a key deterrent. These incentives must be complemented by targeted green financing strategies, including green bonds and concessional loans, to attract private sector participation and reduce the burden on public finances.

In addition, public-private partnerships (PPPs) should be leveraged to scale up investment in electric mobility infrastructure. Lessons from successful implementations in Kigali and Cape Town demonstrate that functional collaboration between governments, technology developers, and local innovators yields greater policy traction and practical outcomes. Pilot projects anchored in these partnerships can provide critical insights for mainstreaming sustainable transport in larger cities and informal settlements.

It is also recommended that decentralized green transport systems be piloted in underserved urban and peri-urban areas. The review highlights cases such as small-scale electric vehicle deployments and bike logistics in select African cities, as discussed by Galuszka et al. (2021), which show potential for scalable and inclusive implementation. These pilots must be rigorously monitored and evaluated to inform adaptive policymaking.

Capacity-building and training programs focused on green transport technologies are urgently required. The shortage of technical expertise related to electric vehicle maintenance, battery recycling, and smart fleet management remains a bottleneck in many African countries. Developing regional centers of excellence and fostering university-industry linkages can bridge these gaps and promote knowledge transfer.

## Future Research Directions

Building on the findings and limitations of this systematic review, future studies should pursue several critical avenues to deepen understanding and improve the implementation of sustainable green motorized transportation in Africa. Longitudinal research is essential to assess the enduring impact of transportation interventions. Most of the current studies are limited to short- or medium-term scopes, which may not capture delayed effects of policy implementation, technological adoption, or behavioral changes. Extending the timeframe of analysis will provide richer insights into sustainability trajectories.

There is also a need to examine the long-term effectiveness and adaptability of green mobility solutions under evolving socio-economic and environmental conditions. Assessing the resilience of electric vehicle infrastructure, policy mechanisms, and public acceptance over time can help identify which interventions are viable in the long run. Exploring country-specific variations in policy implementation, technological readiness, and socio-political contexts will further advance context-sensitive insights. Comparative analyses across African nations, or between urban and rural contexts, can uncover localized barriers and enablers of sustainable transport systems.

Integrating interdisciplinary approaches that combine insights from environmental science, engineering, behavioral economics, and public policy will enable a comprehensive evaluation of trade-offs between industrial growth, environmental protection, and social equity in transportation. In addition, investigating innovative financing models such as public-private partnerships, climate financing instruments, and results-based funding can provide practical strategies to overcome investment gaps and accelerate the rollout of green transport infrastructure in resource-constrained settings. Targeting these research directions will contribute significantly to the evidence base required for designing equitable, scalable, and resilient transport solutions across the African continent.

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## Appendix A

### Full Study Appraisal Matrix

| S/No | Study | Methodology | Appraisal Tool Used | Evidence of Appraisal Criteria Applied | Quality Criteria Met | Risk of Bias | Overall Quality |
|---|---|---|---|---|---|---|---|
| 1 | Akpan & Chinguwa et al. (2019) | Experimental Design | MMAT | Clear objective, innovative method, valid measurement tools, appropriate analysis, reproducible | 5/5 | Low | High |
| 2 | Thondoo et al. (2020) | Quantitative Health Impact Assessment | MMAT | Defined research question, representative sample, statistical relevance, moderate control of confounders | 4/5 | Low | High |
| 3 | Mosissa et al. (2023) | Analytic Hierarchy Process (AHP) | MMAT | Structured methodology; limited socio-economic context analysis | 4/5 | Moderate | Medium |
| 4 | Palk et al. (2020) | Geospatial Modeling Analysis | MMAT | Advanced analysis techniques, consistent interpretation, and a well-documented process | 5/5 | Low | High |
| 5 | Adegun et al. (2021) | Systematic Review | CASP | Clearly focused question, systematic search, appraisal of included studies | 8/10 | Moderate | Medium |
| 6 | Masilela & Pradhan (2021) | Life Cycle Sustainability Assessment | MMAT | Logical methodology lacks breadth in data sources | 3/5 | Moderate | Medium |
| 7 | Ayetor et al. (2023a) | Technical Feasibility Study | MMAT | Comprehensive data collection, reliable modeling, and valid technical assumptions | 5/5 | Low | High |
| 8 | Ayetor et al. (2023b) | Progress Assessment | MMAT | Comparative insights: regional context considered; lacking in socio-economic depth | 4/5 | Low | High |

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|---|---|---|---|---|---|---|---|
| 9 | Morimoto (2022) | Survey Analysis | MMAT | Structured questionnaire, relevant variables, moderate representativeness | 4/5 | Moderate | Medium |
| 10 | Chakwizira (2022) | Policy and Planning Assessment | CASP | Well-structured policy analysis; clearly stated aims; lacks cross-national data | 7/10 | Moderate | Medium |
| 11 | Quaye et al. (2022) | Case Study | CASP | Rich qualitative data, grounded in real context, limited generalizability | 8/10 | Low | High |
| 12 | Ayetor et al. (2021) | Empirical analysis using emission data | MMAT | Emission impact analysis, real-world data from Ghana and Rwanda, lacks policy framing | 4/5 | Moderate | Medium |
| 13 | Qin et al. (2023) | Case study approach | CASP | Infrastructure development insights: weak coverage of sustainable practices | 7/10 | Moderate | Medium |
| 14 | Awad et al. (2023) | Cross-country analysis | MMAT | Macro-level correlation analysis; missing regional context specificity | 4/5 | Moderate | Medium |
| 15 | Rajé et al. (2018) | Urban pollution assessment | CASP | Nairobi-focused; limited empirical validation of suggested practices | 6/10 | Moderate | Medium |
| 16 | Aladejare & Nyiputen (2023) | Ecological impact assessment | MMAT | Identifies ecological drivers; limited regional focus | 4/5 | Moderate | Medium |
| 17 | Naeem et al. (2023) | Statistical analysis of environmental data | MMAT | Strong empirical grounding; lacks economic feasibility insights | 5/5 | Low | High |
| 18 | Akinsola et al. (2022) | Quantitative analysis | MMAT | Urban-industrial linkage focus lacks pollution mitigation focus | 4/5 | Moderate | Medium |
| 19 | Jensen & Whitfield (2022) | Case study (Ethiopia) | CASP | Global supply chain insights lack implementation detail | 7/10 | Moderate | Medium |
| 20 | Okereke et al. (2019) | Socio-technical transition framework | CASP | Visionary framework; implementation guidelines absent | 8/10 | Low | High |
| 21 | Musah et al. (2023) | Policy analysis | CASP | Investment and climate focus; loose financial-inclusion connection | 7/10 | Moderate | Medium |
| 22 | Aminu et al. (2023) | Econometric modeling | MMAT | Pollution-haven hypothesis explored; strong statistical rigor | 5/5 | Low | High |
| 23 | Ibrahim et al. (2022) | Mixed-method approach | MMAT | Mixed-method robustness; lacks quantified emission gains | 4/5 | Moderate | Medium |
| 24 | Lin et al. (2015) | Time-series data analysis | MMAT | Temporal data strength: outdated findings | 5/5 | Low | High |
| 25 | Katoto et al. (2019) | Health impact assessment | MMAT | Health linkage made; lacks sector specificity | 4/5 | Moderate | Medium |
| 26 | Ofori et al. (2023) | Econometric analysis | MMAT | Energy efficiency drivers modeled; strategy validation missing | 4/5 | Moderate | Medium |
| 27 | Ofori et al. (2022) | Governance and policy review | CASP | Energy policy discussion lacks implementation guidance | 6/10 | Moderate | Medium |
| 28 | Appiah et al. (2022) | Policy analysis and case studies | CASP | Highlights investment attraction via deregulation; lacks socio-political depth | 7/10 | Moderate | Medium |
| 29 | Agyeman & Doran (2021) | Rural infrastructure evaluation | MMAT | Links transport to poverty alleviation; lacks long-term empirical validation | 4/5 | Moderate | Medium |
| 30 | Wimbadi et al. (2021) | UNEP report analysis | CASP | Advocates of decarbonization are weak on local tech readiness | 7/10 | Moderate | Medium |
| 31 | Angnunavuri et al. (2019) | Policy review on urban mobility | CASP | Supports sustainable mobility; lacks practical integration due to governance issues | 7/10 | Moderate | Medium |
| 32 | Posada (2018) | Policy analysis on vehicle efficiency | CASP | Pushes fuel economy standards; overlooks stakeholder resistance | 7/10 | Moderate | Medium |
| 33 | Codjoe & Atiglo (2020) | Forum-based strategic analysis | CASP | Formulates strategies for vehicle regulation; enforcement gaps noted | 7/10 | Moderate | Medium |
| 34 | Nethengwe (2022) | Case study in South Africa | CASP | Critiques early green strategies: government inertia not resolved | 6/10 | Moderate | Medium |
| 35 | Collett & Hirmer (2021) | Policy coherence analysis | CASP | Governance gaps identified; community roles neglected | 6/10 | Moderate | Medium |

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|---|---|---|---|---|---|---|---|
| 36 | Ojo et al. (2023) | Policy innovation assessment | CASP | Freight innovations supported; regulation fragmentation is an issue | 7/10 | Moderate | Medium |
| 37 | Mensah & Addo (2020) | Cross-border policy review | CASP | Advocates harmonized policies; lacks enforcement insights | 6/10 | Moderate | Medium |
| 38 | Nyarko & Boateng (2021) | PPP evaluation in transportation | CASP | Supports PPPs; stakeholder alignment concerns | 6/10 | Moderate | Medium |
| 39 | UNECA (2016) | Regional policy analysis | CASP | Regional governance analyzed; lacks accountability discussion | 6/10 | Moderate | Medium |
| 40 | Ali & Wako (2024) | Comparative policy study | CASP | Cross-country policy comparison; diffusion barriers unexamined | 7/10 | Moderate | Medium |
| 41 | Mwangi & Njoroge (2023) | Impact assessment study | MMAT | Socio-economic effects explored; lacks regional variation analysis | 4/5 | Moderate | Medium |

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# An Empirical Study for Transforming Egyptian Seaports into Smart Ports Through Suggesting a Strategic Roadmap

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## Abstract

***Purpose**: This study aims to develop a structured roadmap for transforming Egyptian seaports into smart ports by aligning with international standards to enhance operational efficiency, sustainability, and global competitiveness.*

***Design/methodology/approach:** Using a quantitative research methodology, the study conducts an extensive literature review to identify critical pillars of smart port readiness, including digitalization, operational efficiency, safety and security, sustainability, cybersecurity, and human resources. Primary data was gathered through online surveys distributed to port managers and maritime industry experts to assess the current state of Egyptian ports.*

***Findings:** The study identifies several gaps in the current infrastructure and practices of Egyptian ports, notably in automation, digital integration, and cybersecurity. Based on empirical data, it proposes a phased roadmap to smart port development focusing on strategic improvements in digitalization, automation, sustainability, and workforce capabilities.*

***Research implications:** This research provides a theoretical framework for assessing smart port readiness; however, its scope is limited to quantitative methods and the specific context of Egyptian ports. Broader generalizability may require comparative studies across different regions or the inclusion of qualitative data.*

***Practical implications:** The roadmap offers actionable insights for policymakers, port authorities, and stakeholders seeking to enhance port operations through smart technologies. It supports the design of phased interventions to address existing gaps and ensure a sustainable transformation.*

***Originality:** This study contributes a context-specific, data-driven roadmap tailored to the unique needs of Egyptian ports. It fills a gap in the literature that predominantly focuses on ports in more developed economies. It offers a replicable framework for other developing countries aiming for smart port transformation.*

***Keywords:** Smart ports, digital transformation, automation, cybersecurity, sustainability, Egyptian ports.*

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# Introduction

A port is both a platform and a node in the worldwide maritime transportation network, as well as a driver of global economic and trade growth (Lee *et al*., 2016). Because the port system is such an essential part of the global economic system, the primary incentive for port development is a combination of industrial evolution, market systems, and port competition (Gonzalez *et al*., 2020).

All facets of social and economic life are being impacted by the ongoing digitalization that is currently taking place throughout the world. Despite this, economies and cultures have changed in a variety of ways over time. Technology has been daringly expanding into new fields (Karas, 2020), which will undoubtedly influence the quality of port service shortly. Simultaneously, several port environments, such as port administrations, terminals, shipping lines, transportation businesses, logistics companies, and other service providers, must regard technology adoption as a long-term development process (Bessid *et al*., 2020). Regarding this, Maritime transport chains could become more flexible and efficient as a result of digitalization (Raza *et al*., 2023). Moreover, Ports that digitize their operations provide a platform for other parties in the cargo, freight, and passenger environments to benefit (Becha *et al*., 2020).

In the current digital age, ports confront fierce competition in the global supply chain. The competitiveness and sustainability of the national economy are enhanced by smart ports, which are high-performing ports that use information and communications technology to provide a range of smart applications (Alzate *et al*., 2024). Furthermore, Optimizing the use of the existing infrastructure is the primary objective of digital innovation, which is an essential component of ports that aim to be competitive (Yau *et al*., 2020).

## 1.2 Research Background and Rationale

This research is considered a continuation of the previous study prepared by the authors (Farahat *et al*., 2025); in the latest study, the readiness of Egyptian ports to transform into smart ports was studied, focusing on critical issues such as human resource development, automation, sustainability, safety, and cybersecurity. Semi-structured interviews with port managers, experts, and stakeholders were done using a qualitative, deductive method. Thematic analysis of these interviews gave vital insights into Egypt's accomplishments and obstacles in adopting smart ports. Notably, the study concluded major advances in Egyptian port automation, particularly through the use of Terminal Operating Systems (TOS), while emphasizing human resource development as a major concern due to training gaps and resistance to change. While the first research successfully described the conceptual framework shown in Figure (1) for smart port adoption, it focused on identifying the key pillars and evaluating the current state of Egyptian ports. However, it did not conduct an empirical study on the correlations between the variables conducted from the literature and interviews.

This research aims to complete this research process by empirically examining these relationships. Specifically, it investigates how human resources development, automation in port operations, sustainability requirements, port security, and safety measures, cybersecurity systems, digitalizing port systems, and the integration of the port community influence the readiness of Egyptian ports for smart port transformation.

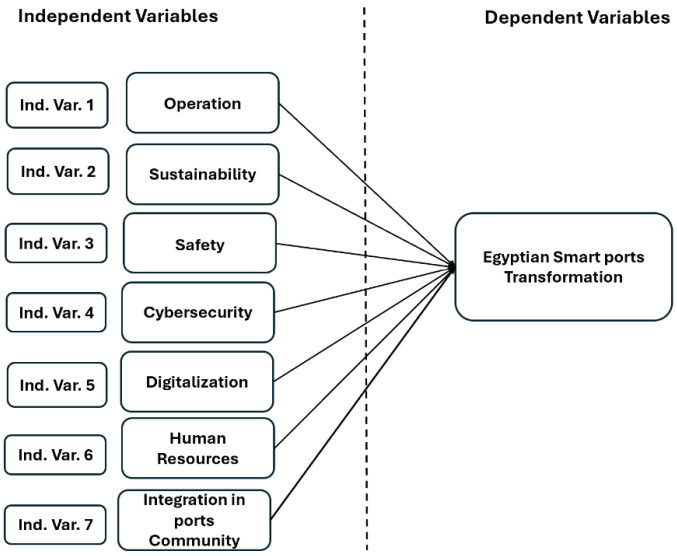


Figure 1: Conceptual Framework conducted from Initial Research

# Literature Review

## 2.1 Conceptualizing Smart Ports

The idea of a "smart port," which first emerged in 2011, suggests using new technology to improve the performance and transparency of traditional port services by enhancing their dynamic and interactive capabilities (Paraskevas *et al*., 2024). Ports are beginning to consider themselves "smart" as a result of this major digital transformation. Processes are being digitalized, and communities inside the port are becoming more linked, resulting in considerable improvements in operational efficiency, regulatory compliance, and customer satisfaction (Molavi *et al*., 2020). Smart ports, being vital nodes in the world's supply chain, have the ability to

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serve as logistics information exchange hubs for their regional transportation ecosystem. The new technological foundation of smart ports, autonomous ships, digital rail, smart containers, smart contracts, and many more intelligent technologies linked via a port's digital information hub will result in tremendous value gains (Triska *et al*., 2024).

The smart port has been identified in multiple ways. These definitions all have one thing in common: they express a technology-centric mindset. Nonetheless, (Karli *et al*. 2021) defined smart ports as "sustainable ports that utilize facilities and port infrastructure in the most effective way possible by employing digital technology at the port efficiently, aiming for maximum revenue at the lowest possible cost." They have worries about worker safety and security, making use of renewable energy resources, and conducting energy and environmental management, and they have added financing elements in their definition of a smart port. The primary rationale for adding finance in the smart port dimension is that smart ports serve the same purpose as traditional ports. As a result, finances are vital. (Rajabi. *et al*. 2018) Explained that a smart port is completely automated and has all of its equipment and infrastructure connected by the IoT (Internet of Things). They said that the smart port's primary objectives are energy awareness, economic development, and effective logistical operations and that IoT is actually what propels the productivity of smart ports.

A smart port is more than just a digital technology application. Smart ports are essential for advancing and bolstering international trade since they incorporate digitalization and fourth-industrial revolution technology (Behdani, 2023). Being "smart" means making a port more competitive and appealing to consumers and users as well as the general public (Lee *et al.,* 2016). Smart port takes into account the needs of port terminal logistics operators. In addition, a smart port enhances the security, dependability, and fluidity of information exchanges and real-time decision-making by relying on the automation of the port terminal's operations and equipment as well as the interconnection of the stakeholders in the port logistics chain (Douaioui *et al*. 2018). It is advised (Sakty. 2016) that stakeholders and seaport authorities promote quality jobs and working conditions, encourage technology investment, implement a single window concept, spread out tracking and tracing technologies, improve the capacity and quality of the infrastructure, improve the environmental and waste management systems, and develop and implement sustainable energy action to overcome the challenges and obstacles facing the transformation of ports into smart logistics nodes.

### 2.2 Lessons Learned from Successful Smart Ports Implementations

Successful smart port implementations worldwide demonstrate that digitalization, automation, and sustainability are key to enhancing port efficiency, competitiveness, and environmental responsibility. The Port of Hamburg integrates smart logistics and energy management to optimize transport flows, reduce emissions, and improve operational efficiency through IoT-based cloud networks (Smart Port Development Policies in Asia and the Pacific, 2021). Singapore's TUAS Port is set to become fully automated by 2040, utilizing AI-driven systems like SAFER and OptEVoyage to streamline vessel arrivals and improve supply chain resilience (PSA Singapore, OptEVoyage, World Port Sustainability Program). The Port of Rotterdam leverages Industry 4.0 technologies, including IoT, AI, and digital twins, to optimize logistics, reduce waiting times, and advance toward full automation (Port of Rotterdam, 2024). These cases highlight that successful smart ports prioritize real-time data integration, sustainability, and collaborative management, reinforcing their role in the future of global maritime trade (Navigate to the Future: Maritime 2050, 2019)

The existing smart ports that are present worldwide show that smart ports are more productive, competitive, and efficient. To increase security, reduce energy, and accomplish more with less, port organizations seek smart ports to use real-time data with a collaborative management style. (Navigate to the Future: Maritime 2050, 2019). Green and digital smart ports have improved access to resources for sustainable development, industrial settings, and logistics. These automated ports prioritize maritime environmental considerations while using the latest technologies. There are several key pillars driving smart port efforts around the world, and while each has its own focus, many of them tend to overlap and reinforce one another.

The most advanced smart ports are working on energy management and environmental impact and have a strategy to deal with these issues. On the opposite, other ports are working on multifunctional initiatives (Molavi *et al*., 2020). So, this research explores the influence of different smart port variables, providing a tailored roadmap for transforming Egyptian ports into smart ports. This roadmap will allow port authorities and managers to improve key areas and increase their efficiency, preparing them for smart port transformation in accordance with global standards and sustainable development needs.

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### 2.3 Hypothesis Development

This research investigates the transformation of Egyptian ports into smart ports by examining critical variables that influence this transformation. The study builds upon prior findings presented in the conceptual framework developed for Egyptian ports, where key pillars were identified, including human resources development, automation in port operations, sustainability requirements, port security, and safety measures, cybersecurity systems, digitalizing port systems, and integration of the port community. Based on the variables identified through the literature review and insights gained from semi-structured interviews with experts, the following hypotheses were developed in alignment with the formulated conceptual framework.

- H1: Human resources development has a significant impact on Egyptian smart port transformation.
- H2: There is a significant impact of automation in port operations on Egyptian smart port transformation.
- H3: Sustainability requirements have a significant impact on Egyptian smart port transformation.
- H4: Port security and safety measures have a significant impact on Egyptian smart port transformation.
- H5: Cybersecurity systems have a significant impact on Egyptian smart port transformation.
- H6: Digitalizing port systems has a significant impact on Egyptian smart port transformation.
- H7: The integration of the port community has a significant impact on Egyptian smart port transformation.

## Methodology

### 3.1 Research Structure

This study employs a deductive approach to investigate the readiness of Egyptian ports for smart port transformation. The research is divided into phases. The first phase identifies the key pillars of smart ports through a comprehensive review of previous studies. The second phase involves a survey analysis, which is based on correlation analysis and structural equation modeling (SEM), to validate the theoretical framework and assess the readiness of Egyptian ports for smart transformation. Then, a roadmap is conducted, offering deeper insights into how elements interact to support or hinder the transformation to a smart port.

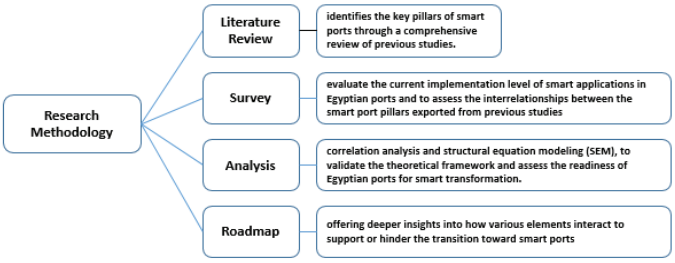


Figure 2: Research structure

Source: Own Elaboration

### 3.2 Data Collection and Sampling

The study's second phase utilized a structured survey to evaluate the readiness of Egyptian ports for smart transformation. The survey, designed based on hypotheses (H1-H7) derived from a comprehensive literature review, consisted of 25 Likert-scale questions organized into nine sections. These sections are as follows:

1. Socio-demographic information
2. Human resources development (H1)
3. Automation in port operations (H2)
4. Sustainability requirements (H3)
5. Port security and safety measures (H4)
6. Cybersecurity systems (H5)
7. Digitalizing port systems (H6)
8. Integration of the port community (H7)
9. Open-ended questions

The research population included 427 entities, comprising 412 Alexandria Navigation Chamber-registered enterprises and 15 Egyptian commercial ports. These stakeholders were chosen because commercial ports play an important role as trade and logistics hubs, processing the vast majority of Egypt's imports and exports. Their readiness for smart transformation has a direct impact on the country's economic performance and global competitiveness.

The study employed a cluster random sampling method, dividing the population into location-based groups, with ports and their stakeholders as clusters. A sample size calculator determined a minimum of 203 respondents for statistical validity, and data was collected from 210 employees in Egypt's ports and port stakeholders.

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### 3.3 Analysis

To test the hypothesis, SPSS and AMOS 18 were employed to apply correlation analysis and structural equation modeling (SEM) to examine relationships between factors and smart port transformation. The research evaluated reliability and validity and carried out frequency analysis, confirmatory factor analysis, normality testing, and multicollinearity analysis.

Correlation analysis is utilized to point out the significance of relationships among different variables influencing smart port transformation. Structural equation modeling (SEM) is then used to validate and test the study hypothesis, leading to a well-documented and systematic Knowledge of variables that affect smart port readiness. Having developed a roadmap and the major components of making Egyptian ports smart ports, SEM is an all-encompassing way of analyzing several interactions at once, giving further insight into how different components interface to enable or hinder change. Ethical concerns were given due consideration while conducting the research. Participants were informed about the purposes of the research, the voluntary nature of participation, and their freedom to withdraw at any point. The responses of participants were maintained as anonymous and confidential to protect data and participants' privacy.

## Results

This section evaluates the preparedness of Egyptian ports for transitioning into smart ports by examining key elements, including the development of human resources, the level of automation, efforts toward sustainability, cybersecurity measures, digitalization processes, and the integration of the port community. The following section presents the quantitative analysis and hypothesis validation.

### 4.1 Survey Sample and Population:

The research population was drawn from the 412 companies registered with the Alexandria Navigation Chamber, along with 15 commercial ports in Egypt, encompassing a wide range of stakeholders. This selection results in a total population size of 427 entities.

Commercial ports and their stakeholders were selected as the research population for the reason that the majority of Egypt's imports and exports pass through commercial ports, which serve as trade and logistics hubs. Their readiness for smart transformation has a direct impact on the country's economic performance and global competitiveness.

Non-commercial ports, such as military, fishing, and recreational ports, were excluded. The reason for excluding these ports is because they play a little part in international trade and commerce. Their contribution to the national economy and trade efficiency is minimal when compared to commercial ports, making them less relevant to a study on smart port transformation. Furthermore, previous research has primarily focused on commercial ports because of their importance in trade and economic activity. This emphasis on commercial ports strengthens the rationale for excluding non-commercial ports.

A cluster random sampling method will be employed to select the study sample. According to (Acharya *et al.* 2013), this is a two-step procedure that divides the population into location-based groups, such as villages, schools, facilities, and blocks. In this study, the clusters are defined as ports and their stakeholders. The study sample is calculated using the sample size calculator, which calculates the minimum number of necessary samples to meet the desired statistical constraints. These resulted in a sample size of 203, which means 203 or more Surveys are needed to have a confidence level of 95% that the real value is within ±5% of the surveyed value.

### 4.2 Respondent Profile

The descriptive statistical analysis examines the characteristics of 210 Egyptian employees based on work position, years of experience, and education level using percentage analysis. The results indicate that 43.3% hold managerial positions, 24.3% are in administrative roles, 11.4% specialize in technical roles, and 21% occupy other roles. Regarding experience, 69% have over 10 years of experience, while 11.4% have 7-10 years. In terms of education, 39% hold a bachelor's degree, 43.8% have a master's degree, and 17.1% possess a doctorate.

Table 1: Respondents' profile

| 1. | Frequency | Percent | Total |
|---|---|---|---|
| **Work Position** | | | |
| Manager | 91 | 43.3 | 210 |
| Technical | 24 | 11.4 | |
| Administrative Staff | 51 | 24.3 | |
| Other | 44 | 21.0 | |
| Work Years | | | |
| Less than one year | 6 | 2.9 | 210 |
| 1-3 | 16 | 7.6 | |
| 4-6 | 19 | 9.0 | |
| 7-10 | 24 | 11.4 | |
| More than 10 | 145 | 69.0 | |

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| 1. | Frequency | Percent | Total |
|---|---|---|---|
| Level of Education | | | |
| Bachelor | 82 | 39.0 | 210 |
| Master | 92 | 43.8 | |
| Doctorate | 36 | 17.1 | |

### 4.3 Descriptive Analysis

Descriptive analysis is essential to gain an understanding of the data to be analysed. In this research, descriptive statistics are employed for each variable in the study. These statistics include standard deviation, minimum, maximum, and mean, as shown in Table 2.

Table 2: Descriptive analysis of research variables

| | N | Mini-mum | Maxi-mum | Mean | Std. De-viation |
|---|---|---|---|---|---|
| Human Resources Development | 210 | 1.00 | 5.00 | 2.6190 | 1.01549 |
| Automation in Port Operations | 210 | 1.00 | 4.00 | 1.7238 | .75768 |
| Sustainability Requirements | 210 | 1.00 | 5.00 | 2.4000 | .86506 |
| Port Security and Safety Measures | 210 | 1.00 | 3.00 | 1.7619 | .64182 |
| Cybersecurity Systems | 210 | 1.00 | 5.00 | 1.8190 | .71593 |
| Digitalizing Port Systems | 210 | 1.00 | 5.00 | 1.8476 | .74860 |
| Integration of the Port Community | 210 | 1.00 | 4.00 | 1.7524 | .66030 |
| Egyptian Smart Port Transformation | 210 | 1.00 | 5.00 | 1.8429 | .76344 |

Source: Own Elaboration

To prepare the data for analysis, responses to the 25 Likert-scale statements were grouped to create composite scores for each of the seven key pillars: Human Resources Development (HRD), Automation in Port Operations (APO), Sustainability Requirements (SR), Port Security and Safety Measures (PSSM), Cybersecurity Systems (CS), Digitalizing Port Systems (DPS), and Integration of the Port Community (IPC). Each pillar was assessed through 2 to 4 related statements. For each participant, the average of the relevant statements was calculated to generate a single score representing that specific construct. These composite scores formed the basis for the descriptive statistics, correlation analysis, reliability and validity testing, and structural equation modeling used in the study. It is important to note that some statements were excluded from the final analysis due to low factor loading during validity testing. The complete survey, along with the alignment of each statement to its corresponding construct, is provided in Appendix A.

### 4.4 Validity and Reliability Testing

The section verifies that the study's variables possess validity and reliability to guarantee accurate measurement and interpretation. The researchers assessed validity by employing Average Variance Extracted (AVE) and Factor Loadings (FL) to evaluate the effectiveness of their measures in representing the intended concepts. AVE scores were all above 0.5 and FL values above 0.40, acceptable thresholds (Hair *et al*., 2016; Yong and Pearce, 2013). Reliability, reflecting the consistency and reliability of the findings, was tested via the KMO test and Cronbach's alpha. According to the literature, Cronbach's alpha values of between 0.7 and 0.9 are strong consistency, while values below 0.6 suggest weak reliability (Sürücü and Maslakci, 2020). Among all variables, Human Resources Development (HRD) proved to be the most reliable.

$$\alpha = .933,\ AVE = 83.226\%,\ KMO = .853$$

The factors of Automation in Port Operations (APO), Sustainability Requirements (SR), Port Security and Safety Measures (PSSM), Cybersecurity Systems (CS), Digitalizing Port Systems (DPS), and Integration of the Port Community (IPC) display moderate to high levels of reliability (Cronbach's α from .700 to .825) along with validity. The Egyptian Smart Port Transformation (ESPT) demonstrates strong internal consistency.

$$\alpha = .849,\ AVE = 76.920\%,\ KMO = .704.$$

Overall, the results show that the data is both reliable and valid, making it suitable for further analysis (Rozali *et al.,* 2022).

Table 3: Validity and reliability test

| Variables | KMO | AVE % | Cron-bach's α | State-ments | Factor Loading |
|---|---|---|---|---|---|
| Human Resources Development | .853 | 83.226 | .933 | HRD1 | .773 |
| | | | | HRD2 | .865 |
| | | | | HRD3 | .877 |
| | | | | HRD4 | .815 |
| Automation in Port Operations | .500 | 77.278 | .703 | APO1 | .773 |
| | | | | APO2 | .773 |
| Sustainability Requirements | .500 | 85.138 | .825 | SR2 | .851 |
| | | | | SR3 | .851 |
| Port Security and Safety Measures | .500 | 84.920 | .821 | PSSM1 | .849 |
| | | | | PSSM3 | .849 |
| Cyber security Systems | .500 | 76.766 | .700 | CS1 | .768 |
| | | | | CS3 | .768 |

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| Variables | KMO | AVE % | Cron-bach's α | State-ments | Factor Loading |
|---|---|---|---|---|---|
| Digitalizing Port Systems | .500 | 83.108 | .793 | DPS1 | .831 |
| | | | | DPS2 | .831 |
| Integration of the Port Community | .500 | 75.302 | .700 | IPC1 | .753 |
| | | | | IPC2 | .753 |
| Egyptian Smart Port Transforma-tion | .704 | 76.920 | .849 | ESPT1 | .773 |
| | | | | ESPT2 | .831 |
| | | | | ESPT3 | .703 |

Source: Own Elaboration

*HRD = Human Resources Development, APO = Automation in Port Operations, SR = Sustainability Requirements, PSSM = Port Security and Safety Measures, CS = Cybersecurity Systems, DPS = Digitalizing Port Systems, IPC = Integration of the Port Community, ESPT = Egyptian Smart Port Transformation. The number following each acronym (e.g., "1" in HRD1) indicates the order of the statement within that construct.

### 4.5 Testing Research Hypotheses

Both correlation analysis and structural equation modeling (SEM) are used to assess the research hypotheses. Correlation analysis was employed to estimate the strength and direction of relationships between variables, using a correlation coefficient ranging from -1 to +1. Since the data wasn't the typical bell-curve shape, a different type of correlation called Spearman's rank correlation (Spearman's r) is used. This method works well when data isn't normally distributed. Table 3 shows the correlation coefficients among the research variables, revealing the following key findings:

- Human resources development (HRD) and Egyptian smart port transformation (ESPT) have a moderate positive correlation ($r = 0.354$, $p < 0.05$).
- ESPT has a moderate positive correlation with automation in port operations (APO) ($r = 0.411$, $p < 0.05$).
- A weak to moderate positive correlation exists between ESPT and sustainability requirements (SR) ($r = 0.222$, $p < 0.05$).
- ESPT shows a weak but significant positive correlation with port security and safety measures (PSSM) ($r = 0.171$, $p < 0.05$).
- A moderate positive correlation is found between ESPT and cybersecurity systems (CS) ($r = 0.281$, $p < 0.05$).
- ESPT also has a moderate positive correlation with digitalizing port systems (DPS) ($r = 0.287$, $p < 0.05$).
- A moderate positive correlation is observed between ESPT and integration of the port community (IPC) ($r = 0.338$, $p < 0.05$).

These correlations suggest that Egypt's transition to smart ports is influenced by various factors, including human resources development, automation in port operations, sustainability requirements, cybersecurity systems, digitalization of port systems, and the integration of the port community.

Table 4: Research variable correlation matrix

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| HRD | R | 1.000 | | | | | | | |
| | Sig. | . | | | | | | | |
| | N | 210 | | | | | | | |
| APO | R | .301** | 1.000 | | | | | | |
| | Sig. | .000 | . | | | | | | |
| | N | 210 | 210 | | | | | | |
| SR | R | .506** | .311** | 1.000 | | | | | |
| | Sig. | .000 | .000 | . | | | | | |
| | N | 210 | 210 | 210 | | | | | |
| PSSM | R | .201** | .313** | .431** | 1.000 | | | | |
| | Sig. | .003 | .000 | .000 | . | | | | |
| | N | 210 | 210 | 210 | 210 | | | | |
| CS | R | .065 | .341** | .093 | .400** | 1.000 | | | |
| | Sig. | .346 | .000 | .180 | .000 | . | | | |
| | N | 210 | 210 | 210 | 210 | 210 | | | |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DPS | R | .250** | .393** | .374** | .456** | .329** | 1.000 | | |
| | Sig. | .000 | .000 | .000 | .000 | .000 | . | | |
| | N | 210 | 210 | 210 | 210 | 210 | 210 | | |
| IPC | R | .277** | .315** | .332** | .321** | .331** | .387** | 1.000 | |
| | Sig. | .000 | .000 | .000 | .000 | .000 | .000 | . | |
| | N | 210 | 210 | 210 | 210 | 210 | 210 | 210 | |
| ESPT | R | .354** | .411** | .222** | .171* | .281** | .287** | .338** | 1.000 |
| | Sig. | .000 | .000 | .001 | .013 | .000 | .000 | .000 | . |

Source: Own Elaboration

### 4.6 Structure Equation Modelling

The study used Structural Equation Modeling (SEM) to examine the impact of various factors on Egyptian smart port transformation. The findings shown in Table 5 are summarized as follows:

- **Human Resources Development (H1)**: A significant positive impact on Egyptian smart port transformation was found (p = 0.000, estimate = 0.209). HRD explains 14.8% of the variance, supporting the hypothesis.
- **Automation in Port Operations (H2)**: A significant positive effect on smart port transformation was observed (p = 0.043, estimate = 0.395). Automation explains 15.7% of the variance, supporting the hypothesis.
- **Sustainability Requirements (H3)**: No significant effect on smart port transformation (p > 0.05). Sustainability requirements explain only 6.5% of the variance, so the hypothesis is not supported.
- **Port Security and Safety Measures (H4)**: A non-significant negative effect was found (p > 0.05). These measures explain 2.8% of the variance, so the hypothesis is not supported.
- **Cybersecurity Systems (H5)**: No significant effect on smart port transformation (p > 0.05). Cybersecurity systems explain 6.0% of the variance, so the hypothesis is not supported.
- **Digitalizing Port Systems (H6)**: A non-significant negative effect was found (p > 0.05). Digitalizing port systems explains 4.4% of the variance, so the hypothesis is not supported.
- **Integration of the Port Community (H7)**: A significant positive effect on smart port transformation was found (p = 0.018, estimate = 0.538). It explains 10.9% of the variance, supporting the hypothesis.

In conclusion, human resources development, automation in port operations, and integration of the port community have significant positive impacts on Egyptian smart port transformation, while sustainability requirements, port security, and safety measures, cybersecurity systems, and digitalizing port systems do not.

Table 5: Structure equation modelling results

| | | | Estimate | S.E. | C.R. | P | Hypoth-esis | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| ESPT | <--- | HRD | .209 | .068 | 3.062 | .002 | $H_1$ | .148 |
| ESPT | <--- | APO | .395 | .195 | 2.025 | .043 | $H_2$ | .157 |
| ESPT | <--- | SR | .048 | .118 | .408 | .683 | $H_3$ | .065 |
| ESPT | <--- | PSSM | -.282 | .182 | -1.543 | .123 | $H_4$ | .028 |
| ESPT | <--- | CS | .050 | .206 | .242 | .809 | $H_5$ | .060 |
| ESPT | <--- | DPS | -.115 | .123 | -.936 | .349 | $H_6$ | .044 |
| ESPT | <--- | IPC | .538 | .227 | 2.367 | .018 | $H_7$ | .109 |

## Discussion

When examining Egyptian ports' preparations for the transition to smart ports, the research correlation analysis revealed several strong correlations; however, certain elements had inconsequential relationships.

***Development of Human resources*:** It is easy to recognize the connections between smart port preparedness, staff training, and the continuous pursuit of new and creative methods to enhance port operations. New opportunities frequently call for new methods of completing tasks that involve human labor. This result supports the findings of Robert (2020) and Paraskevas (2024), who noted a connection between the employment of smart technology in port operations and personnel training and development. Ports with robust HRD programs are better able to handle the complexity of smart port technologies, according to a number of studies.

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***Port automation:*** port automated systems increase productivity, enhance the efficiency of workflow, and minimize mistakes. Berlin and Eriksson (2021) noted that applying automation technologies in port operations, especially in handling cargo, management of inventory, and logistics integration, is associated with enhanced operational flexibility and efficiency. These attributes are considered crucial indicators of successful smart port transformations. This viewpoint is also strengthened by Karas (2020a), who concludes that automation can lead to considerable time and operational cost savings, factors that are central to enhancing the competitiveness of a port in the global market.

***Integration of Port Community:*** Othman *et al*. (2022) and Gizelis *et al*. (2022) emphasize that the progression of smart port development is significantly dependent on robust collaboration and efficient communication channels among shipping lines, port authorities, and diverse stakeholders. The positive link between port community integration and readiness for smart port transformation highlights how crucial stakeholder engagement is to make the transition a success. According to their results, prompt information exchange and well-coordinated decision-making are essential cornerstones of a well-functioning, integrated smart port system.

***Sustainability Requirements***: Notwithstanding the widespread international focus on sustainable development, the outcomes of this investigation did not establish a statistically significant association between a port's readiness for smart technologies and adherence to sustainability criteria. This observation diverges from the findings reported by Garg *et al*. (2023), who posited sustainability as a salient factor propelling the evolution of smart ports. In the Egyptian context, however, this connection appears weaker, possibly due to the current prioritization of technological advancements over environmental concerns. Min's (2022) work confirms that although sustainability is essential, it becomes secondary to smart port initiatives where operational efficiency and cost-effectiveness dominate.

***Port Security and Safety Measures:*** Another important insight is that port safety and security measures do not show a significant connection with smart port readiness. Simola *et al*. (2023) explain that although security and safety are significant aspects of port operations, they do not necessarily contribute to smart port readiness unless they are designed to respond to the requirements of smart technologies specifically. Reva (2020) backs this up, suggesting that existing security standards are frequently insufficient to manage the complex and growing difficulties connected with smart port systems.

***Cybersecurity Systems:*** Douaioui *et al*. (2018) highlighted the critical dependence of smart port efficiency on strong and secure network management systems. However, the absence of a material relationship between smart port preparedness and cybersecurity infrastructure in this study shows that this industry is underdeveloped and requires further combined effort and dedicated investment. Reva (2020) points out that many ports still haven't put in place full cybersecurity strategies that match their digital transformation goals. Progress in this crucial area of development may be hampered in the Egyptian context by the scant empirical data relating cybersecurity to smart port readiness.

***Digitalising Port Systems:*** Moreover, Egyptian ports are still in the early stages of digitalization, as reflected in the weak correlation observed between smart port readiness and the digitalization of port infrastructure. While digitalization is a fundamental component of smart port development, Dalaklis *et al*. (2022) note that its impact may not be immediately apparent. This is particularly true in contexts where foundational infrastructure and technological adoption are still emerging, as Karas (2020) also points out.

## Roadmap to Smart Port Transformation

This research offers a model for the evolution of Egyptian ports towards smart port status. The proposed framework, informed by both empirical investigation and a review of literature, centers on the strategic incorporation of technology, the effective alignment of stakeholder interests, and the enhancement of operational processes. While Existing smart port initiatives need more coordination and integration to achieve long-term sustainability. The plan employs a staged approach that starts with gap analysis before moving on to prioritizing automation, cybersecurity, and sustainability. Pilot programs are then implemented to pilot and harden technologies, develop workforce capability, and ensure seamless system integration. Regular evaluation and optimization cycles provide long-term scalability by monitoring progress and optimizing systems for technology refreshes. This stepwise approach aims to transform Egyptian ports while fostering a secure and sustainable working environment.

1. Assessment Phase
    - Conduct comprehensive audits of existing infrastructure and digital readiness.
    - Identify key gaps in automation, cybersecurity, and sustainability.

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- Benchmark against leading global smart ports.

2. Prioritization Phase
   - Focus on integrating digital solutions with current port operations.
   - Develop training programs for port employees on smart port technologies.
   - Encourage policy reforms to facilitate digitalization efforts.
3. Pilot Testing and Scaling
   - Conduct small-scale pilot projects to evaluate automation solutions and digital platforms.
   - Assess cybersecurity measures to ensure resilience against cyber threats.
   - Expand successful projects to multiple port terminals.
4. Implementation Phase
   - Implement comprehensive digital infrastructure, including IoT technologies and AI-driven analytics.
   - Enhance cybersecurity processes to safeguard sensitive data.
   - Collaborate with international smart port leaders to transmit technology.
5. Continuous Monitoring and Optimization
   - Apply key performance indicators (KPIs) to measure smart port efficiency.
   - Create real-time data dashboards for operational monitoring.
   - Ensure ongoing training and policy adaptations to keep pace with technological advancements.

Table (6) outlines the key principles guiding the transformation of Egyptian ports into smart ports, along with the main challenges standing in the way—such as internal resistance to change, limitations in available technology, and environmental constraints. It also suggests realistic, actionable steps to overcome these obstacles and clearly identifies the various organizations involved, from local port authorities to national ministries, ensuring each has defined responsibilities. The goal is to develop a port infrastructure that is technologically advanced, well-coordinated, and highly efficient. These findings are grounded in both survey responses and expert perspectives, offering a reliable basis for assessing where Egyptian ports currently stand and what steps are needed moving forward. If the proposed plan is carried out effectively, it can significantly boost operational performance, help ports meet global standards, and enhance Egypt's position in the international maritime sector.

Table 6: Summary of key transformation concepts, barriers, solutions, and entities in charge

| Transformation Concept | Barriers | Solutions | Institution in Charge |
|---|---|---|---|
| **Digital Infrastructure & Automation** | Limited automation in cargo tracking and terminal operations, reliance on manual labor | Implement a full Terminal Operating System (TOS) and Port Community System (PCS) for real-time tracking and integration. | Ministry of Transport, Port Authorities |
| **Human Resources Development** | Resistance to technology, lack of skills in digital tools | Develop training programs for employees on digital tools and incentivize technology adoption. | Port Authorities, Port Training Institute (PTI), Egyptian Ministry of Manpower |
| **Stakeholders' integration** | Poor integration among port community members | Implement a unified digital system for stakeholders, such as a single-window platform. | Ministry of Transport, Port Community System |
| **Cybersecurity Systems** | Inadequate cybersecurity infrastructure to protect port systems | Establish a multi-layered cybersecurity protocol with regular security audits and employee training | Ministry of Communications, Port IT Department |
| **Digitalization of Port Systems** | Reliance on paper-based processes, low digital integration | Transition to digital documentation and develop an integrated Port Community System | Ministry of Transport, Port IT Department |
| **Financial Investment & Infrastructure** | Budget constraints, limited investment in advanced infrastructure | Establish public-private partnerships (PPPs) and seek international funding for smart port infrastructure | Ministry of Investment, Port Authorities |

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| | | | |
|---|---|---|---|
| **Customer and User Experience** | Long waiting times, limited digital communication with port users | Develop a user-friendly interface for port customers with real-time tracking and support | Port Authorities, Port IT Department |
| **Resilience and Adaptability** | Limited agility in responding to market and operational disruptions | Implement flexible infrastructure and agile decision-making processes for rapid adaptation to changes | Port Management, Port Authorities |
| **Environmental Monitoring** | Poor monitoring of emissions and pollutants | Implement environmental monitoring systems for tracking emissions, noise, and water quality. | Ministry of Environment, Port Management |
| **Energy Management** | High energy consumption and reliance on non-renewable sources | Shift to renewable energy sources (solar, wind) and implement energy-saving measures | Ministry of Electricity, Port Authorities |

# Conclusion and Implications

## 7.1 Conclusion

To increase operational effectiveness, sustainability, and global competitiveness, traditional Egyptian seaports must be converted into smart ports. The findings of this study identified several key dimensions exerting a considerable influence on a port's preparedness for smart transformation. These critical aspects encompass human resource development, the automation of port operations, and the integration of the port within the broader community. These are some of the main areas in facilitating the smart port ecosystem transformation. However, areas such as elevated sustainability standards, enhanced port security, stronger safety cultures, advanced cyber defense solutions, and digital enablement have not shown a significant correlation with Egyptian port preparedness for smart transformation. This emphasizes how urgently more organized, awareness-driven planning is required in order to adequately handle these crucial areas. Egyptian ports can start implementing smart technology gradually, increase operational effectiveness, and become closer to global best practices by taking a methodical, gradual approach. This would ultimately help the growth of a stable and competitive maritime industry.

## 7.2 Implications

This study offers a noteworthy theoretical advancement to the developing body of knowledge concerning smart port transformation. Specifically, it emphasizes the significant roles of human resource development, automation implementation, and the inclusion of the port community within the smart port paradigm. These topics are in line with global debates that highlight how digital transformation can improve port operations. At the same time, the results indicate a need for more theoretical research into the relationship between smart port readiness and sustainability, cybersecurity, and safety measures—at least in the context of Egyptian ports. From a practical perspective, the study offers useful guidance for stakeholders, port authorities, and policymakers committed to advancing smart port strategies. Promoting automation and investing in the development of human capital should be prioritized to support digital adoption. In parallel, achieving effective integration with the broader port community requires coordinated action among all involved parties. While sustainability and security were not found to be strong influencing factors in this study, they remain essential for aligning Egypt's port sector with international benchmarks. With a clear and phased implementation plan, Egyptian ports stand to improve their efficiency, strengthen long-term resilience, and elevate their position in the global maritime landscape.

## 7.3 Research Limitations and Further Studies

Despite the contributions of this research, several limitations should be acknowledged. One of the main constraints is the relatively small sample size, as the study was based on feedback from a limited group of stakeholders within Egyptian ports. Expanding the sample to include a broader range of ports and industry perspectives would likely yield more comprehensive insights. Additionally, the research relies primarily on stakeholder opinions rather than an in-depth technical evaluation of port infrastructure, which may limit the precision of the smart port readiness assessment.

Another limitation is the study's exclusive focus on Egyptian ports, which may reduce the generalizability of the findings to other regions with different economic, regulatory, and technological environments. Moreover, smart port transformation is a rapidly evolving process driven by continuous technological advancements. As such, a longitudinal approach would be necessary to capture its dynamic nature and changing impacts over time.

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Given these limitations, future research should consider conducting comparative studies between Egyptian ports and international counterparts to identify best practices and remain aligned with global developments. Further investigation is also needed into the influence of national policy frameworks and international regulations on the pace and success of smart port initiatives. In addition, studies exploring the integration of green technologies, renewable energy solutions, and cybersecurity strategies will be essential to shaping resilient and future-ready port systems. Addressing these areas would deepen our understanding of smart port transformation and support more informed decision-making in the maritime sector.

### List of Figures:

1. Figure (1) Conceptual Framework conducted from Initial Research
2. Figure (2) Research Structure

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## Appendix A

Survey

**An Empirical Study for Transforming Egyptian Seaports into Smart Ports Through Suggesting a Strategic Roadmap**

This appendix presents the structured survey questionnaire used to assess the readiness of Egyptian ports for smart transformation. The 25 Likert-scale items are grouped under seven investigative pillars corresponding to the study's hypotheses (H1–H7). All items were rated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).

**Section 1: Demographics and Background Information**

- What is your current role at the port/Company?

Manager
Technician
Administrative Staff
Other (please specify)

-How many years have you worked in the port industry?

Less than 1 year
1-3 years
4-6 years
7-10 years
More than 10 years

-Level of Education

PhD
MSc
BSc

**Section 1: Dependent Variable - Egyptian Smart Port Transformation (ESPT)**

1- The adoption of smart port technologies will positively impact the economic performance of Egyptian ports (ESPT 1)

2- The implementation of smart technologies will significantly improve the efficiency of port operations in Egypt. (ESPT 2)

**Section 2: Human Resources Development (H1)**

1. The overall quality of training programs provided by ports is excellent. (HRD 1)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

2. Ports staff are frequently provided with opportunities for professional development (e.g., workshops, seminars, courses).

Strongly Agree (HRD 2)
Agree
Neutral
Disagree
Strongly Disagree

3. The port invests adequately in employee skill development. (HRD3)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

4. The training programs are highly relevant to the technological advancements in the port industry (e.g., automation, digitalization). (HRD 4)
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

5. Human resources development is crucial for the successful transformation into a smart port. (HRD 5)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

**Section 3: Automation in Port Operations (H2)**

6. Implementing automation in port operations will significantly enhance the efficiency of port activities. (APO 1)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

7. Automation technologies (e.g., automated cranes and self-driving vehicles) are essential for smart port transformation. (APO 2)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

8. The Egyptian port has already seen improvements in operations due to automation technologies. (APO 3)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

**Section 4: Sustainability Requirements (H3)**

9. Enforcing sustainability requirements will facilitate the transformation of Egyptian ports into smart ports. (SR 1)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

10. The Egyptian port has implemented effective sustainability practices (e.g., waste management and energy efficiency). (SR 2)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

11. Sustainability initiatives are prioritized in Egyptian port's strategic plans. (SR 3)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

**Section 5: Port Security and Safety Measures (H4)**

12. Improving port security measures will positively affect the smart port transformation. (PSSM 1)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

13. Egyptian ports have made significant improvements in safety measures in recent years. (PSSM 2)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

14. Enhanced security measures are essential for the successful implementation of smart port technologies. (PSSM 3)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

**Section 6: Cybersecurity Systems (H5)**

15. Implementing robust cybersecurity systems is crucial for the smart port transformation. (CS 1)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

16. Egyptian ports have effective cybersecurity measures in place to protect against digital threats. (CS 2)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

17. The risk of cyber threats is a major concern in the digitalization of port operations. (CS 3)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

**Section 7: Digitalizing Port Systems (H6)**

18. Digitalizing port systems will enhance the efficiency and effectiveness of port operations. (DPS 1)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

19. Digital systems are well-integrated into our daily port operations. (DPS 2)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

**Section 8: Integration of the Port Community (H7)**

20. There is a significant positive relationship between the integration of the port community and the transformation of Egyptian smart ports. (IPC 1)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

21. Collaboration with stakeholders (e.g., shipping companies and logistics providers) is crucial for the smart port transformation. (IPC 2)

Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree

**Section 9: Open-Ended Questions**

22. Please describe any specific initiatives or projects that have significantly contributed to the smart port transformation in your experience.

23. What additional measures or resources do you believe would help further the smart port transformation at Egyptian ports?

# The Influence of Logistics Preparedness on Resilient Disaster Relief Operations: Evidence from Disaster Relief Operations Practitioners in Humanitarian Organizations in Tanzania

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## Abstract

***Purpose**: This study investigates the influence of logistics preparedness on resilient disaster relief operations (DROs) in Tanzania, aiming to assess how preparedness strategies contribute to humanitarian operational resilience.*

***Design/Methodology/Approach:** The study is guided by stakeholder theory and resource orchestration theory. It adopts a positivist research philosophy and an explanatory research design. Data were collected through questionnaires and interviews from 192 humanitarian logistics and DRO practitioners in Tanzania. The sample size was determined using Slovin's formula and selected through stratified systematic random sampling. Data were analyzed using descriptive statistics and multiple linear Regression with the aid of SPSS version 27.*

***Findings:** The results indicate a strong and statistically significant positive influence of logistics preparedness on resilient disaster relief operations, with an R-squared value of 0.75. All six preparedness factors showed significant effects ($p < 0.05$). Key contributors include sustainable and flexible financial resource allocation ($\beta = 0.312$, $p = 0.003$), skilled personnel deployment ($\beta = 0.276$, $p = 0.002$), investment in financial risk management ($\beta = 0.256$, $p = 0.022$), capacity building ($\beta = 0.189$, $p = 0.011$), physical resource maintenance ($\beta = 0.224$, $p = 0.035$), and sustainable practices ($\beta = 0.198$, $p = 0.005$).*

***Research Limitations/Implications:** The study is geographically limited to specific regions in Tanzania. Future research should consider broader national or cross-country comparisons and longitudinal analysis.*

***Practical Implications:** Humanitarian organizations should prioritize logistics preparedness initiatives and develop structured plans that strengthen response capacity and resource readiness.*

***Social Implications:** Enhancing logistics preparedness can lead to more effective, timely, and community-sensitive disaster response systems.*

***Originality/Value:** This study adds empirical evidence and theoretical depth to humanitarian logistics by validating stakeholder and resource orchestration theories. It highlights the strategic role of preparedness in ensuring resilient disaster relief operations.*

***Keywords:** Logistics Preparedness, Disaster Relief Operation, Resilient Disaster Relief Operation, and Humanitarian Organizations.*

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# 1. Introduction

## 1.1. Background of the Study

In the past years, it has been evident that the occurrence of disasters has greatly affected the lives of humans due to delayed responses and ineffectiveness in the process of rescue and distribution of relief supplies to the affected population (Nayak & Choudhary, 2020; Masoumi et al., 2021). The occurrence of disasters and the repercussions to human lives have necessitated researchers' and policymakers' attention to instituting measures, models, and procedures to minimize the impact of natural and manmade disasters (Negi, 2022). Considering the devastating effects of disasters, both natural and manmade, governments worldwide are instituting agencies, departments, and organizations that are responsible for ensuring proper coordination for rescue and provision of relief supplies once a disaster strikes (Wankmüller and Reiner, 2019). In the efforts to develop mechanisms to solve the aftermath of disasters, there are also polices and regulations imposed as interventions for proper disaster relief operations (Dohale et al., 2022).

Furthermore, efforts to achieve effectiveness in disaster relief operations have been a huge concern globally and have been the major challenge for government and humanitarian organizations (Dubey et al., 2020; Magalhães, 2020). It is evident that natural disasters globally pose significant challenges to supply chain management and logistics (Wendler, 2017). These challenges are linked to rescue efforts, resources, logistics integration, and distribution of relief supplies. Extensive studies have internationally highlighted these complexities and challenges faced during relief operations (Aghsami et al., 2024). In recent years, research studies have extensively analyzed response operations for major disasters in countries like India, Pakistan, and Malaysia, revealing key practices and challenges, particularly in post-disaster relief. In this regard, the major challenges include manpower shortages, insufficient equipment, lack of coordination, and communication barriers (Argollo da Costa et al., 2014; Argollo da Costa et al., 2015). Similar challenges were explained in relation to the Ludian earthquake in China by Wang (2024). The studies above posed the severity of the disasters and emphasized the Integration of the critical role of logistics in managing complexities in relief operations. Despite these insights, there remains a need for further research and exploration to enhance efficiency in humanitarian logistics associated with relief operations. The current studies have not adequately linked humanitarian logistics practices to the resiliency of disaster relief operations.

Further to scholars' and research contributions, relief efforts coordination and severity of disasters on lives have garnered attention from several humanitarian organizations, NGOs, international humanitarian organizations, and governments (Altay et al., 2018; Dubey et al., 2019). Disasters are explained to challenge the ability of nations to protect people's lives (Altay & Green, 2006). As reported by the Centre for Research on the Epidemiology of Disasters (CRED), in 2019 alone, around 395 natural disasters resulted in approximately 11,756 deaths, affected 95 million people, and incurred costs of nearly $130 billion (CRED, 2020). A similar trend was observed in 2018 with 281 events causing 10,733 fatalities (Dubey et al., 2019b). The statistics show that the frequency of disaster occurrence has increased from 220 annually in the mid-1990s to around 360-420 per year currently.

Recent research studies in Africa highlight the challenges and possible strategies for effective disaster relief operations. The studies narrated the key barriers, which include lack of planning and preparedness, logistics, coordination, and public perception (Baidoo, 2018; Maghsoudi & Moshtari, 2020). In efforts to address the issues, researchers provided suggestions that are related to improving training, stakeholder coordination, and increased funding of disaster relief operations (Okdinawati et al., 2019; Baidoo, 2018). However, despite these numerous contributions, effectiveness in coordination remains a significant challenge (Gupta et al., 2016). In Ghana, researchers narrated a problem in disaster relief operations to be slow response time, resource availability and coordination of resources, management of relief supplies, and coordination among relief actors (Owusu-Kwateng et al., 2017). In Zimbabwe, Mbohwa (2010) narrated logistics challenges in disaster relief operations, including poor hospital service quality, inadequate infrastructure, and funding issues.

Furthermore, in the context of East African nations, humanitarian logistics in relation to disaster relief operations are not immune to the narrated logistical and resource challenges. Natural and manmade disasters have been shown to cause huge effects on the population due to these challenges, as disasters also cause disruption in the supply chain, which necessitates robust business continuity plans (Kangogo et al., 2013). A well-structured and planned humanitarian logistics can play a crucial role in emergency responses, as shown by Kimori Osumo & Omwenga (2024). In Uganda, Korir et al. (2023) emphasize the importance of transport, order processing, information flow, and inventory management for effective disaster response. However, challenges like inadequate finances, inefficiencies

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in relief supplies distribution, and poor coordination persist (Orach et al., 2013). There are disasters that have impacted populations in Kenya, Rwanda, Uganda, and Congo. The literature contribution from these nations intensifies the common challenges in relief operations, like poor coordination of relief operations, resource and capacity to respond to disasters rooted in preparedness and effective distribution of relief supplies and coordination of relief efforts (Bahal'Okwibale 2018; Shears & Garavan 2020; Sospeter 2023; Komorowski & Karume 2015; Agrawal 2013). Research also noted the inefficiencies in information distribution and the lack of specialized information systems specific to disaster operations coordination (Kumar & Luthra, 2020; Kumar & Lakshmi, 2015; Tarei et al., 2024).

In the Tanzanian context, in recent years, disasters have had severe impacts, with floods from 2015 to 2020 resulting in 307 deaths, affecting 317,907 individuals, and destroying 50,588 houses. Regions like Mwanza, Morogoro, and Dar es Salaam have been significantly affected. For example, the 2015 rainstorm in Kahama resulted in 47 deaths, affecting 3,500 people and destroying 634 houses (PMO, UNDRR, 2022). Tanzania has also experienced notable maritime disasters, such as the MV Nyerere ferry tragedy in 2018 and the MV Spice Islander disaster in 2011 (PMO, UNDRR, and CIMA, 2019). As this current study intended to examine the effect of humanitarian logistics preparedness on resilient disaster relief operations, in this examination, the study applied resource stakeholders' theory and orchestration theory. Previous studies provide a path into the application of these theories in humanitarian logistics and disaster relief operations. For example, Jusoh et al. (2024), in their study about humanitarian operations performance through logistics preparedness, focused on resource-based theory and stakeholders' theory in the context of humanitarian logistics in Malaysia. Ruiter & de Vries (2024), in their paper about the efficacy of humanitarian aid, suggested that effective resource orchestration and stakeholder engagement can enhance operational efficacy, which is also suggested by Tosi & Marty (2024). Mutebi et al. (2023), in their paper about stakeholder expectations, inter-organizational coordination, and procurement practices among humanitarian organizations, primarily focus on Stakeholder Theory, emphasizing the interconnectedness of stakeholder expectations, inter-organizational coordination, and procurement practices in humanitarian organizations, particularly in Uganda, which is also discussed in the research work by Nawazish et al. (2023). On the other hand, Fu et al. (2022) emphasize leveraging stakeholder resources to enhance disaster resilience, aligning it with resource-based theory and stakeholder theory.

### 1.2. Statement of the Problem

Disaster relief operations need proper handling when associated with alleviating the suffering of affected people. Mendy et al. (2023) stated that properly handled humanitarian logistics and disaster relief operations can enhance the efficiency and effectiveness of aid delivery, and this can help to ensure timely assistance to affected populations. Furthermore, Osumo & Omwenga (2024) in their study in Kenya pointed out that proper humanitarian logistics can enhance disaster relief operations by ensuring efficient resource allocation, improving response times, and fostering strategic alliances. Ito et al., (2014) highlighted that poor logistics operations can lead to severe issues, termed "the second disaster," and this is due to inadequate disaster preparedness and a lack of understanding among involved sectors, ultimately hindering effective relief efforts and response efficient, furthermore Shaqiri (2018) and Zain et al., (2021) propounded that these factors in totality hinder timely and efficient disaster relief operations, ultimately impacting human life and property during emergencies. This highlights the need for better emergency planning to mitigate risks and disruptions.

Furthermore, protection of human lives and alleviating the suffering of the people in a disastrous situation has been a primary concern for different governments and established humanitarian organizations and agencies (Bizzarri, 2012; Holthus et al., 2020; Ayiek & Deng, 2024). Efforts are undertaken to ensure proper coordination in humanitarian efforts. In Tanzania, several efforts have been undertaken to mitigate the impact of disasters, from creating public awareness campaigns fostering community engagement in rescue operations to the establishment of international relief organizations and non-governmental organizations (NGOs) (Majamba, 2023; Msemo et al., 2021; Rutaba, 2023; Rutaba, 2022). The Government of Tanzania has also established the Disaster Management Division under the Prime Minister's Office (PMO) for disaster relief coordination. The Government has also enacted policies and Acts to support Disaster Risk Management (DRM) across various sectors, addressing issues like environment and climate change, public health, food security, and military support in public emergencies (Mboera et al., 2012; Daly et al., 2015; Majamba, 2023; Msemo et al., 2021). Despite these efforts, the frequency and severity of disasters continue to rise, revealing persistent gaps and inefficiencies in disaster relief operations: from coordination of activities, data sharing, rescues, and relief supplies storage and distribution (Sama, 2023; Majamba, 2023; Zain et al., 2023; Salam & Khan, 2020; Sahay et al., 2016). These

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inefficiencies in disaster relief operations have led to an increase and intensified suffering of the disaster-affected people (PMO, UNDRR, 2022; CIMA, 2019; Sama, 2023; Majamba, 2023).

Furthermore, despite the pressing need for improved disaster operations management, there has been limited empirical evidence and contributions to humanitarian logistics and disaster relief operations in Tanzania. Existing studies, such as those by Masoud (2022) and Rutaba (2022, 2023), have explored various aspects of humanitarian logistics performance, challenges in disaster management, and logistics cooperation in effective disaster relief operations. In addition to that, Koka et al. (2018) examined disaster preparedness and the response capacity of regional hospitals, while Mbura (2014) focused on disaster management and persistent flooding. However, these studies have not adequately articulated the critical aspects of logistics factors for adaptive and rapid disaster relief operations; the studies clearly noted that poor disaster relief operations are amplified by poor logistical coordination.

Therefore, this current study will focus on examining the Contribution of humanitarian logistics preparedness to resilient disaster relief operations. The outcomes of this research are expected to contribute to the development of comprehensive humanitarian logistics contingency plans, which are crucial for ensuring effective disaster relief operations in Tanzania (Rutaba, 2023; Rutaba, 2022; Kovács & Spens, 2007; Apte, 2010).

# 2. Literature Review

## 2.1 Theoretical Review

### 2.1.1 Stakeholder Theory

R. Edward Freeman is widely recognized as the founder of this theory, who has fully articulated the framework in his 1984 book “Strategic Management: A Stakeholder Approach” (Paas, 1996; Kivits & Sawang, 2021). Freeman defined a stakeholder as “any group or individual who can affect or is affected by the achievement of the organization’s objectives” (Kivits & Sawang, 2021). The theory has since gained significant traction in corporate, governmental, and academic spheres (Kivits & Sawang, 2021).

In practical premises and applicable narrations, this theory illustrates that the occurrence of disaster affects all the stakeholders and their activities, and generally they affect the whole business of organizations’ operations and disrupt the normal operations of supplies and supply chains (Gunasekaran et al., 2018; Freeman, 2010). In order to deal with the disruption and maintain order in the systems, the stakeholders need to be well prepared and to effectively coordinate their resources and strive to maintain the resilience of the systems and ensure continuity of operations in the normal way by absorbing the shocks (Carter, 2015; Pfeffer and Salancik, 1978, 2003).

Ademola (2014) demonstrated that the effectiveness of disaster operations done by humanitarian organizations is definitely determined by the preparedness of the stakeholders with vested interests in disaster relief operations (Godam, 2019; Shan-Bing, 2008; Parboteeah, 2018). Stakeholder Theory underscores the importance of engaging all relevant parties—local authorities, relief organizations, and community groups—in disaster preparedness. By aligning the interests of these stakeholders, the theory ensures that logistics preparedness benefits everyone involved and fosters effective coordination. This approach, which emphasizes value creation and stakeholder relationships, enhances resilience and ensures a timely and efficient disaster response (Freeman et al., 2004; Sachs & Rühli, 2011; Mitchell et al., 1997).

### 2.1.2 Resource Orchestration (RO) Theory

Coupling to the grounding of stakeholder’s theory, as the theory depicts the relationship between stakeholders, is essential to also include their existence with the supporting resources in relief operations, which takes us to the complementarity of resource pooling reflecting from orchestration theory (RO). RO, according to Sirmon et al. (2007, 2011), is presented as a rich theoretical foundation combining the resource-based view theory and dynamic capability view theory into one theoretical framework for the purpose of overcoming the constraints addressed by each. Both theoretical views contend that possessing resources and capabilities is hard and difficult to duplicate, that they are valuable, rare, non-substitutable, and inimitable. However, on these theories, despite the identification of criteria that resources and capabilities must suffice to be viewed as the source of sustained competitive advantage, later were criticized because none explain how strategically organizations can leverage their resources and capabilities to gain the value creation outcomes (Malik et al., 2021; Gligor et al., 2022).

In this study, in essence, Resource Orchestration (RO) theory is highly relevant to understanding how logistics preparedness contributes to resilient disaster relief operations, hence complementing stakeholder

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theory to include resource pooling as one of the critical aspects powering preparedness. The theory provides a framework for strategically managing and mobilizing resources like supplies, Personnel, and infrastructure under challenging disaster conditions. RO emphasizes not only possessing valuable resources but also effectively deploying them through structuring, bundling, and leveraging.

### 2.2 Empirical Literature Review: Logistics Preparedness and Disaster Relief Operations:

Humanitarian logistics (HL) plays a critical role in disaster relief operations, facing numerous challenges that require effective management. Recent studies have highlighted the increasing frequency of natural disasters and the need for improved HL practices (Negi, 2022; Negi & Negi, 2020). Key issues include coordination among stakeholders, resource allocation, and supply chain efficiency (Shafiq & Soratana, 2019). To address these challenges, researchers have proposed frameworks focusing on preparedness and response stages, emphasizing the importance of standardization and lean management principles (Negi & Negi, 2020; Shafiq & Soratana, 2019). The Multiple Aggregation Prediction Algorithm (MAPA) model has been suggested to manage challenges and address specific relief needs (Sreedharan et al., 2020). While most studies employ qualitative approaches, there is a need for more quantitative research and practical implementation of proposed frameworks (Shafiq & Soratana, 2019; Sreedharan et al., 2020). Improving HL operations can significantly reduce the impact of disasters on affected populations (Negi, 2022).

Negi (2022) conducted a study on a humanitarian organization's perspective on humanitarian logistics challenges in disaster relief operations. The study aimed to illustrate the challenges and issues impeding HL in relief operations. In this regard, the key objective of this specific study was to emphasize how HL is critical in disaster management and the identification of the issues affecting humanitarian organizations (HO) in managing logistics during disasters. A qualitative approach was employed in the study to investigate the problems affecting HL and supply chains, using a literature analysis on disaster management. The results managed to identify several challenges, which reinforced why it is necessary to carry out additional research in HL operations, including resource mobilization and logistics planning challenges, collaboration challenges, and illustrated the limitations of the literature on these aspects. The study concluded that, as natural disasters occur often throughout the world, it is essential and critical to properly and efficiently handle logistics when a disaster strikes. It should be noted that not all disasters can be prevented, but the impacts can be minimized by adequate efforts and mechanisms for preparedness and humanitarian logistical operations.

The efficiency of humanitarian assistance post-disaster relies heavily on the capabilities of logisticians to procure, transport, and deliver necessary provisions swiftly (Sahay et al., 2016). Unlike conventional logistics, humanitarian logistics focuses on delivering aid such as food, water, medical support, and shelter (Kovacs & Spens, 2009; Tatham, Spens & Kovacs, 2017). These operations often face logistical complexities, issues in HL management, disaster management policies, and financial constraints (Thevenaz & Resodihardjo, 2010). Kwateng, Hamid, and Debrah (2017) conducted research in Ghana focusing on disaster relief logistics, particularly examining emergency relief coordination and inventory management effectiveness. Their study revealed delays in relief item delivery, challenges in resource availability, and inefficiencies in inventory management and coordination among relief actors, which stemmed from a lack of proper planning and preparedness.

Reflecting on the 2017 Kermanshah earthquake, Maghsoudi and Moshtari (2020) conducted a study on challenges in disaster relief operations, and the study managed to identify the constraints during the recent disaster relief operations in a developing country, where the humanitarian response is quite dominated by the national domestic actors, with a minor role of international involvement. The study used a case study research design here, and the main data sources were semi-structured interviews with 43 key participants involved in the disaster relief operations. The findings of the study suggest that humanitarian practitioners deal with a number of constraints during disaster relief operations. One side of the challenges is associated with humanitarian logistics (stressing needs assessment, supplies procurement, storage, transportation, and distribution), all of which are largely discussed in the literature. On the other side, it involved the growing concern about the usage of legitimacy regulations, engagement of new humanitarian stakeholders (like social media activists and celebrities), and the usage of social media. The study added that practices relating to these factors have not been extensively studied in the present literature; given their growing influence, more scholarly attention is demanded.

In other aspects, in one of the reputable journals of Humanitarian Logistics and Supply Chain Management, the Journal of Humanitarian Logistics and Supply Chain Management (JHLSCM), from global response to local

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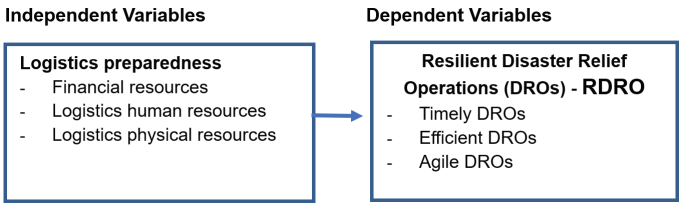
preparedness, Jahre and Jensen (2021) conducted a study on coordination at the 10-year mark of the JHLSCM on empirical contributions on logistics preparedness in relief operations. The authors of the study narrated that there is little empirical Contribution to the study of logistics preparedness in relief operations. Their focus was on the inception of the Journal of Humanitarian Logistics and Supply Chain Management (JHLSCM), logistics coordination, and preparedness, which were identified as important, both in practice and research, but few studies on the topic had been published.

### 2.3 Conceptual Framework

This poses a conceptual framework on the relationship between the independent variables and dependent variables. Independent variable being humanitarian logistics preparedness, and dependent variable being resilient disaster relief operations (facilitate affected ones in a timely, agile, and effective manner)

Figure 1: Conceptual Framework




Source: Researcher's own Construction (2024)

### 2.6 Hypothesis Development

Humanitarian logistics preparedness is crucial for effective disaster relief operations (DROs), but lacks a unified understanding across organizations and research (Jahre et al., 2016; Negi & Negi, 2020). Humanitarian logistics preparedness may be postulated in preparedness in logistics, financial resources, logistics human resources, and logistics physical resources (Jahre et al., 2016). Effective DROs require proper planning, coordination among actors, and adaptation to specific disaster phases (Kovács & Spens, 2007). Researchers suggest that further studies in operations management and research could improve the efficiency of humanitarian logistics, despite its inherently chaotic and complex nature (Apte, 2010). Developing a common understanding and framework for logistics preparedness can enhance visibility and knowledge in this critical field (Jahre *et al.,* 2016). Hence, the study intends to test the relationship between Humanitarian logistics preparedness and resilient disaster relief operations through testing the following hypothesis ($H_1$)

***$H_1$: Logistics preparedness has a significant impact on resilient disaster relief operations in Tanzania***

## 3. Methodology

The study adopted a positivist philosophy, which is useful in this study because of its main characteristics. The study collected data from a large sample size instead of focusing on the details of the research. According to Saunders et al. (2016), focusing on this philosophical undertaking, positivist philosophy helps in the examination of the association between two or more variables. In terms of design, the study adopted an explanatory research design, using a mixed research approach to include quantitative and qualitative data and provide a combined explanation. The study collected both forms of data during the study and then integrated the information to interpret the overall results. Explanatory research design is relevant when researchers aim to explain the relationships between variables (Creswell, 2012).

This study was conducted in Tanzania with the experience of humanitarian logistics and disaster relief practitioners working in humanitarian organizations located in Tanzania. The data were collected from humanitarian practitioners from these Humanitarian Organizations (HOs) located in Tanzania, utilizing the Google Search engine, and as shown in the UNHCR's Humanitarian Situation Report of 2022, most of the Humanitarian Organizations are located in the regions of Dar es Salaam, Dodoma, and Kigoma. The preliminary analysis of the population of humanitarian practitioners makes a population of 369. In this study, the target population comprises humanitarian practitioners from various humanitarian organizations and stakeholders actively engaged in humanitarian logistics and disaster relief operations. The practitioners from HOs present the units of analysis and unit of enquiry of the study. These practitioners from diverse HOs played a vital role in this study as a unit of enquiry by offering their valuable insights and opinions from professional perspectives on the management of HOs and humanitarian supply chain management. Their extensive experience in disaster relief operations positions them as key contributors, ensuring the study's comprehensiveness and relevance to real-world practices.

The study selected a sample of 192 respondents to participate in the study, which was calculated using Slovin's formula. The strength of this formula is that it enables sampling the population with a degree of accuracy, i.e., confidence levels in the statistical test

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and margins of error (Creswell, 2014; Magigi, 2015). In this respect, the study uses 5 % margin of error or confidence level. This sample comprised procurement and logistics specialists, supply chain managers, supply chain specialists, warehouse officers, rescuers, and health logistics practitioners from the humanitarian organizations. These practitioners make up the unit of enquiry for the study. This study included a mapping of sixteen (16) HOs, which were treated as strata, and to ensure effective representation of all practitioners for all the identified HOs in the regions, the sample size of 192 practitioners was proportionally allocated for each stratum. Hence, practitioners of each HOs of the sampling frame were chosen at the proportion of 0.520 (192/ 369).

Using probabilistic sampling techniques, the proportional stratification sampling approach was adopted to ensure adequate representation of the practitioners from identified HOs. According to Creswell (2012), the stratification sampling approach is used when the characteristics of a sample do not balance the population, considering several homogenous groups as supported by John, Mwakalobo, and Bengesi (2019). Practitioners in each stratum (HOs) of the sampling frame were selected at a proportion of 0.520 (192/369). In order to ensure fairness in the selection within the organization, systematic random sampling was used, selecting every second (2nd) practitioner in the preparedness list of practitioners, with corresponding phone numbers and email addresses (where the questionnaire was shared online). As for non-probabilistic sampling procedures, the researcher used purposive sampling to choose the heads of HOs (key informers). The study employed a variety of data collection tools, which enabled the researcher to collect adequate quantitative data and later triangulate the information. The tools included the questionnaires and interviews. The study involved a data collection process through the distribution of copies of the questionnaire to all the respondents, observing the setting of the departments, and an interview schedule was conducted with all respondents identified as heads of units or organizations.

The analysis of data in this study involved both quantitative and qualitative methods. Frequencies and percentages tables were used to analyze and interpret the numerical data. The analysis was guided by the research objective, and the data were coded, edited, and cleaned before being presented in a general table to facilitate further exploration. Descriptive statistics were used to analyze the demographic information of respondents for the qualitative data. The quantitative data were analyzed using linear regression analysis. Linear regression analysis is a statistical method that is used to estimate the relationship between one or more independent variables and a single dependent variable (Dupont, 2009). In this present study, Multiple Linear Regression was used to determine significant factors from potential explanatory variables.

Furthermore, thematic analysis was used to address the qualitative information from the key informants. The thematic analysis is aimed at complementing some of the weaknesses of the quantitative approach (Magigi, 2015). With this, Patton (2002) suggests that quantitative analysis may be too mechanical and unable to extract the feelings, emotions, and subjective responses evidenced in social science. In this analysis, the researcher followed the procedure recommended by Saunders et al. (2016), namely, familiarizing with the collected data, applying the codes to the data, searching for themes, and then identifying the relationships, polishing themes, and testing prepositions. Table 2 below provides an illustration of the variables opted for study and their definitions and variable measurements.

In testing the validity and reliability of the research instruments, they did a meticulous assessment to ensure the rigor, accuracy, and trustworthiness of the data collected. In establishing validity, the study employed multiple strategies. This was done to achieve content validity and construct validity. In this context, content validity was achieved through the Construction of questionnaire items based on well-established literature, including, for example, Jusoh et al. (2024) and Hussain et al. (2022), and to confirm the adequacy of items in measuring the constructs of logistics preparedness and resilient disaster relief operations, further validation was done through expert reviews. Also, a pilot test was conducted among a subset of humanitarian practitioners, which further enabled refinement of ambiguous or redundant items and enhanced the overall clarity and relevance of the instrument.

On the other side, construct validity was reinforced through the critical operationalization of study variables, which ensured alignment between the research objective, hypothesis, and measurement indicators. Further, the application of mixed-methods data collection—incorporating both structured questionnaires and semi-structured interview guides—enabled methodological triangulation, which by far enhanced internal validity by corroborating findings across quantitative and qualitative data sources.

Furthermore, to assess reliability, both test-retest and split-half techniques were employed. The test-retest approach here involved re-administering the same

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instrument to other respondents at different time intervals to evaluate consistency over time, and the split-half method here examined the internal agreement between divided halves of the instrument. In addition to this, Cronbach's Alpha was calculated for each scale, with values calculated that exceeded the acceptable threshold of 0.70, which indicates high internal consistency and reliability of the measurement tools.

Table 2: Assessment of Variable Measurements

| Variable | Definition | Measurement | Instrument |
|---|---|---|---|
| Logistics Preparedness | - logistics financial resources<br>- logistics human resources<br>- logistics physical resources<br>(Jusoh et al., 2024), From these six (6) observable statements, a construct was developed by the researcher | 5-point Likert scale | Questionnaire and interview guide |
| Resilient Disaster Relief Operations (RDRO) | - Timely Disaster relief operations<br>- Efficient Disaster Relief Operations<br>- Agile Disaster Relief Operations<br>(Hussain et al.,2022) | 5-point Likert scale | Questionnaire and interview guide |

Source: Researcher's own Construction (2024).

### 3.8 Ethical Consideration

It is mandatory to adhere to ethical issues when conducting research. Therefore, the procedure for data collection under this study began when research clearance from Mzumbe University was made available to the researcher. All the procedures, including the request for an introduction letter and permission to conduct research, were adhered to prior to the data collection procedure. The research study also observes the ethical principle of beneficence as the study aims to benefit others while promoting their welfare and safety.

Additionally, the consent forms were provided to respondents, which explained the main intention of the research and the usefulness of their participation in the success of the exercise. Also, freedom to withdraw from the study at any time if they wish to do so was stipulated in the consent form to ensure voluntary participation. The ways in which anonymity would be ensured were also clarified to the respondents to ensure the confidentiality of the information provided. The originality of the document was assured through a plagiarism check.

## 4. Findings and Discussion

### 4.1 Demographics of the Respondent

The demography of the respondents is mainly based on the variables that were intended to describe the characteristics of respondents in terms of humanitarian organization region, humanitarian organization category, location, age group, experience, and specialization in disaster relief operations. According to Saunders et al. (2016), these data are used to explain how opinions and behaviors differ, and to check the extent to which the data represent the total population. The summary of the respondent's demographics is presented in Table 3. The respondents who filled out the questionnaire were the practitioners from humanitarian organizations located in Dodoma, Kigoma, and Dar es Salaam. Both technical and support staff were involved. Concerning this, some of the respondents had a relief procurement background, humanitarian supply chain background, relief operations background, and disaster management background. Moreover, after receiving the response from each practitioner, the researcher computed the average scores. Since the scale of the questionnaire ranged from 1 to 5, the average scores were rounded to one decimal place. Besides, the demographic data were also averaged based on their scales and rounded to zero decimal places.

The demography of the respondents shows that most of them (39.6 %) come from the HOs located in Dar es Salaam Region, followed by Dodoma Region (32.3 %), and Kigoma Region (28.1 %). Dar es Salaam Region is leading in terms of respondents because 39.6% of practitioners in HOs of the sampling frame are located in this Region. Kigoma Region is the last leading because only 28.1% of practitioners in HOs of the sampling frame are located in the Region. The study found that most of the HOs in Kigoma have a head office located in Dar es Salaam.

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Besides, the distribution of actual respondents based on the practitioners' HOs categories shows that the Non-Government (Local) category is leading by 41.1% followed by Non-Government (International) (35.9%), and Government (22.9%).

Furthermore, the respondents' age was distributed across all categories, with 9.9%, 53.1%, 29.2%, 7.8% and 0 % in the ranges of 18 to 27, 28 to 37, 38 to 47, 18 to 27, and above 57 years, respectively. This shows that the respondents were of different ages, with a minimum range between 18 and 27, and a maximum of over 57 years. Besides, the majority of respondents were between 28 and 37 years old and 38 and 47 years old. These results suggest that most of the respondents were middle-aged and elderly. According to Kiage (2013), middle-aged and elderly employees have adequate experience to provide the required information. Hence, the present study involved participants of all age ranges, which are representative of the total population.

The linkage with working experience in the environment is essential as it aids in accessing the right knowledge from the participants (Goel, 2016), and one way of enhancing knowledge is through the time spent performing certain activities. Based on this view, the study assessed the level of respondents' experience in disaster relief operations working with HOs. The experience was assessed in terms of the number of years the respondent has spent in disaster relief operations and humanitarian logistics. Findings on experience in disaster relief operations and humanitarian logistics revealed that 24.0% of respondents had experience of more than 10 years, 46.4% of respondents had experience between 5 and 10 years, 28.1% of respondents had experience between 3 and 5 years, and 1.6% of respondents had experience below 3 years. Having 5 years or more of experience indicates that the respondents had been involved in disaster relief operations and humanitarian logistics. Thus, this confirmed that the respondents of this study have adequate experience with the problem investigated by the current study. This finding was also observed by Tan and Wong (2015), who indicate the relationship between experience and organizational performance.

Table 3: Demographic Characteristics of Respondents (N = 192)

| Variable | Category | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Age Group** | 18 – 27 Years | 19 | 9.9% | 9.9% | 9.9% |
| | 28 – 37 Years | 102 | 53.1% | 53.1% | 63.0% |
| | 38 – 47 Years | 56 | 29.2% | 29.2% | 92.2% |
| | 48 – 57 Years | 15 | 7.8% | 7.8% | 100.0% |
| | **Total** | **192** | **100.0%** | **100.0%** | |
| **Work Experience** | 0 – 3 Years | 3 | 1.6% | 1.6% | 1.6% |
| | 3 – 5 Years | 54 | 28.1% | 28.1% | 29.7% |
| | 5 – 10 Years | 89 | 46.4% | 46.4% | 76.0% |
| | More than 10 Years | 46 | 24.0% | 24.0% | 100.0% |
| | **Total** | **192** | **100.0%** | **100.0%** | |
| **Type of Organization** | Government | 44 | 22.9% | 22.9% | 22.9% |
| | Non-Government (Local) | 79 | 41.1% | 41.1% | 64.1% |
| | Non-Government (International) | 69 | 35.9% | 35.9% | 100.0% |
| | **Total** | **192** | **100.0%** | **100.0%** | |
| **Organization Location** | Dodoma | 62 | 32.3% | 32.3% | 32.3% |
| | Dar es Salaam | 76 | 39.6% | 39.6% | 71.9% |
| | Kigoma | 54 | 28.1% | 28.1% | 100.0% |
| | **Total** | **192** | **100.0%** | **100.0%** | |

| | | | | | |
|---|---|---|---|---|---|
| **Practitioner Specialization** | Rescuer | 16 | 8.3% | 8.3% | 8.3% |
| | Supply Chain | 40 | 20.8% | 20.8% | 29.2% |
| | Logistics Officer | 24 | 12.5% | 12.5% | 41.7% |
| | Relief Officer | 31 | 16.1% | 16.1% | 57.8% |
| | Relief Operations Coordinator | 30 | 15.6% | 15.6% | 73.4% |
| | Medical Supply Specialist | 18 | 9.4% | 9.4% | 82.8% |
| | Distribution Officer | 33 | 17.2% | 17.2% | 100.0% |
| | **Total** | **192** | **100.0%** | **100.0%** | |

Source: Data from Survey (2024)

### 4.2 Examination of Data Entry, Missing Data and Outliers

The initial data analysis was conducted to identify errors in the data set in the form of data entry, missing data, and outliers. This is because errors in the data set may compromise subsequent analysis and results. To ensure the data were entered correctly, a double-check approach was performed. The first check was done by verifying all entries on a case-by-case basis. The second check was conducted and verified using descriptive statistics, including mean, standard deviation, and frequency distribution. Missing data are the values of one or more variables that were not obtained for analysis (Hair et al., 2010). Missing data can lead to insignificant results because of the influence they have on data analysis. Hence, it is very important to check the patterns and relationships for missing data and properly handle them. There are three basic techniques for dealing with missing data. These are listwise deletion, pairwise deletion, and mean substitution (Kline, 2011; Schinka et al., 2003). In this study, no missing values were detected. Outliers are cases where the scores are very different from those of others in the dataset (Kline, 2011). In this study, there were no missing values, and there were no cases of outliers.

### 4.3 Descriptive Statistics: Mean. Standard Deviation, Skewness and Kurtosis

Skewness appears in three forms (left: skew < 0, normal: skew ~ 0, and right: skew > 0). Kline (2011) narrated that the value between -1 and 1 is an acceptable range for normality. However, normality is not only tested by skewness alone but also by kurtosis. Kurtosis is defined as a measure of whether the data are flat relative to a normal distribution. Some studies can decide to accept kurtosis and skewness values between -2 and +2 (Kline, 2011), and some accept -3 and +3 for kurtosis (Balanda & MacGillivray, 1988).

The descriptive statistics indicate a generally favorable perception among respondents, with mean values ranging from 3.89 to 4.35 on a five-point Likert scale. The highest-rated aspect is LOP1 (Mean = 4.35), reflecting strong logistics preparedness, while LOP6 (Mean = 3.89) is the lowest but still suggests a positive evaluation. Standard deviations range from 0.79 to 0.98, indicating moderate agreement among respondents, and variance values (0.624 to 0.960) further confirm that responses are relatively consistent without significant dispersion.

The negative skewness values (-1.12 to -0.85) indicate that most ratings lean towards higher scores (4 and 5), suggesting optimism in logistics preparedness. Additionally, kurtosis values (1.02 to 1.65) show that responses are somewhat concentrated around the mean, with LOP1 (1.65) being the most strongly agreed upon aspect. Overall, these results suggest that logistics preparedness is perceived positively, with minor variations across the different components. The consistency in responses and the tendency toward higher ratings highlight a well-established logistics preparedness framework, with opportunities for further strengthening, particularly in LOP6. Therefore, according to Kline (2011), since the values for each measure were between the required range, this shows that the variable of logistics preparedness is normally distributed. Table 5 presents the mean, standard deviation, kurtosis, and skewness of the institutional setup variable.

Referencing the level of agreement as presented in Table 4, Financial Resource Allocation and Risk Management (LOP1 and LOP2). The findings indicate that 65.1% of respondents (39.5% Agree, 25.6% Strongly Agree) affirm the importance of sustainable and flexible financial resource allocation in ensuring continuous readiness and rapid response during emergencies. This result underscores the pivotal role of financial preparedness in enhancing logistics operations, particularly in volatile and unpredictable crises. However, the 28.2% neutral response rate suggests that some organizations may have limited experience in implementing flexible financial resource allocation strategies. Similarly, 64.6% of respondents (42.2% Agree, 22.4% Strongly Agree) acknowledge that investment in financial risk

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management and contingency planning strengthens the resilience and sustainability of logistics operations. The significant level of agreement highlights that proactive financial risk management is a key component of logistics preparedness. However, the 29.0% neutral responses indicate a potential gap in institutional capacity or knowledge regarding contingency planning and its practical application in humanitarian logistics.

Human Resource Capacity Development (LOP3 and LOP4). Human resource capacity plays a central role in logistics preparedness, as it directly influences the ability of humanitarian organizations to mobilize and respond to crises. The data reveals that 70.5% of participants (40.6% Agree, 29.9% Strongly Agree) consider ongoing training and capacity-building initiatives for logistics personnel crucial for maintaining a skilled and adaptable workforce. The absence of disagreement reflects a consensus on the value of continuous capacity-building programs in enhancing logistics preparedness. Additionally, 67.8% of respondents (47.4% Agree, 20.4% Strongly Agree) believe that strategic recruitment and efficient deployment of skilled Personnel enable rapid mobilization and strengthen organizational preparedness. However, the 25.0% neutral responses highlight that while the importance of human resource capacity is widely acknowledged, some organizations may lack the necessary frameworks to link recruitment practices with logistics preparedness outcomes.

Physical Resource Management (LOP5 and LOP6). Prepositioning and effective management of physical resources are essential components of logistics preparedness. The data shows that 73.9% of respondents (51.0% Agree, 22.9% Strongly Agree) agree that adequate prepositioning and maintenance of essential physical resources enhance operational readiness during disaster response. This result highlights the critical role of resource availability and accessibility in ensuring timely and effective emergency response. Similarly, 71.4% of participants (51.2% Agree, 20.2% Strongly Agree) agree that effective resource management and sustainable practices in logistics assets support continuity and adaptability across various disaster scenarios. The emphasis on sustainable logistics practices aligns with the growing need for environmentally responsible humanitarian logistics systems.

Table 4: Descriptive Statistics on the level of agreement of respondents (N=192)

| Variable | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Sustainable and flexible financial resource allocation is essential for ensuring continuous readiness and rapid response (LOP1) | 0 (0%) | 10 (5.1%) | 55 (28.2%) | 77 (39.5%) | 50 (25.6%) |
| Investment in financial risk management and contingency planning enhances the resilience and sustainability of logistics operations during unpredictable crises (LOP2) | 0 (0%) | 8 (4.1%) | 57 (29.0%) | 83 (42.2%) | 44 (22.4%) |
| Ongoing training and capacity-building initiatives for logistics personnel are crucial for maintaining a skilled and adaptable workforce in emergency situations (LOP3) | 0 (0%) | 0 (0%) | 53 (26.9%) | 80 (40.6%) | 59 (29.9%) |
| Strategic recruitment and efficient deployment of skilled Personnel enable rapid mobilization and strengthen the preparedness. (LOP4) | 0 (0%) | 10 (5.1%) | 49 (25.0%) | 93 (47.4%) | 40 (20.4%) |
| Adequate prepositioning and maintenance of essential physical resources, such as vehicles and equipment, enhance operational readiness in disaster response (LOP5) | 0 (0%) | 0 (0%) | 47 (23.9%) | 100 (51.0%) | 45 (22.9%) |
| Effective resource management and sustainable practices in logistics assets support continuity and adaptability across various disaster scenarios (LOP6) | 0 (0%) | 0 (0%) | 47 (23.2%) | 104 (51.2%) | 41 (20.2%) |

Source: Data from Survey (2024)

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Table 5: Descriptive Statistics and Normality Testing for Logistics Preparedness Variables (N=192)

| Item | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|
| LOP1 | 4.35 | 0.79 | 0.624 | -1.12 | 1.65 |
| LOP2 | 4.18 | 0.85 | 0.723 | -1.05 | 1.43 |
| LOP3 | 4.02 | 0.89 | 0.792 | -0.98 | 1.27 |
| LOP4 | 4.10 | 0.82 | 0.673 | -1.08 | 1.38 |
| LOP5 | 4.05 | 0.94 | 0.884 | -0.92 | 1.15 |
| LOP6 | 3.89 | 0.98 | 0.960 | -0.85 | 1.02 |

Source: Data from Survey (2024)

Table 6: Influence of Logistics Preparedness on Resilient Disaster Relief Operation

| Resilient Disaster Relief Operation | Coef. | SE Coef. | T | P |
|---|---|---|---|---|
| LOP1 | 0.312 | 0.045 | 2.79 | 0.003 |
| LOP2 | 0.256 | 0.054 | 2.31 | 0.022 |
| LOP3 | 0.189 | 0.038 | 2.56 | 0.011 |
| LOP4 | 0.276 | 0.048 | 3.21 | 0.002 |
| LOP5 | 0.224 | 0.059 | 2.14 | 0.035 |
| LOP6 | 0.198 | 0.051 | 2.85 | 0.005 |

R-Sq = 0.75 Adjusted R-squared ($R^2$ adj) is 0.73

Referring to Table 6 above, the findings in the table above demonstrate a strong and statistically significant influence of logistics preparedness factors on resilient disaster relief operations. Logistics preparedness is structured with six observed variables, and from this analysis, all six logistics preparedness factors (LOP1–LOP6) exhibit positive and significant coefficients ($p < 0.05$). As for R-squared, there's a relatively high R-squared (0.75) and Adjusted R-squared (0.73), which indicates that 73%–75% of the variation in resilient disaster relief operations can be explained by the logistics preparedness factors. This underscores the critical role of these factors in disaster management. Among the predictors, LOP1 ($\beta = 0.312$, $p = 0.003$) and LOP4 ($\beta = 0.276$, $p = 0.002$) portray the strongest effects. This suggests that these specific logistics preparedness dimensions—potentially related to sustainable and flexible financial resource allocation, strategic recruitment, and efficient deployment of skilled Personnel —are particularly vital in enhancing resilience. The relatively lower coefficients for LOP3 ($\beta = 0.189$) and LOP6 ($\beta = 0.198$) indicate that while these factors still contribute significantly to resilience, their impact may be comparatively less pronounced than that of others. This also suggests that these specific logistics preparedness dimensions—potentially related to Ongoing training and capacity-building initiatives for logistics personnel and Effective resource management and sustainable practices in logistics assets —are particularly vital in enhancing resilience. The practical implication is clear: strategic investment in logistics preparedness can significantly improve disaster response effectiveness. Given the varying magnitudes of the coefficients, future research should explore whether certain logistical capabilities have a more pronounced impact on specific phases of disaster relief, such as preparedness, response, or recovery.

The overall strength of the model suggests that logistics preparedness is a key determinant of resilience in disaster relief operations, emphasizing the need for well-structured planning and resource allocation. The statistical significance of all predictors indicates that a multi-faceted approach to logistics preparedness is essential, ensuring that infrastructure, supply chain coordination, and operational readiness are collectively optimized. Organizations involved in disaster relief should prioritize investments in the most impactful logistics preparedness areas, particularly those represented by LOP1 and LOP4, to enhance response effectiveness. Additionally, the results highlight the necessity of continuous assessment and improvement of logistics capabilities, as even factors with lower coefficients contribute meaningfully to resilience. Future studies could refine these findings by incorporating contextual variables such as geographic challenges, policy frameworks, and real-time data analytics to further enhance disaster preparedness and response strategies.

Table 7: Analysis of Variance (ANOVA)

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 6 | 22.0874729 | 3.6812455 | 89.72 | 0.0000 |
| Residual Error | 185 | 4.8994836 | 0.0265 | | |
| Total | 191 | 26.9869565 | | | |

Source: Data from Survey (2024)

The Analysis of Variance (ANOVA) table 7 above illustrates statistical validation for the regression model examining the effect of logistics preparedness on resilient disaster relief operations. The Regression sum of squares (SS) = 22.0875 out of the Total SS = 26.9870, indicates that a substantial proportion of the variability in resilient disaster relief operations is explained by this model. The Mean Square (MS) for Regression = 3.6812, compared to the Residual MS = 0.0265, highlighting a large difference between the explained and unexplained variance, demonstrating the model's strong predictive power. The analysis of variance (ANOVA) is a valuable tool for evaluating the statistical significance of regression models in this

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context (Brereton, 2019).

The F-statistic (F = 89.72, p = 0.0000) confirms that the overall regression model is statistically significant, meaning that at least one of the logistics preparedness predictors (LOP1–LOP6) has a significant effect on resilient disaster relief operations. Given the extremely low p-value (0.0000), there is strong evidence to reject the null hypothesis that all predictor coefficients are equal to zero, supporting the conclusion that logistics preparedness significantly influences disaster relief resilience. The relatively low residual error suggests minimal unexplained variation, reinforcing the robustness of the model. However, further diagnostics, such as checking for multicollinearity or heteroscedasticity, could enhance confidence in these results. Building on this understanding of logistics preparedness and resilient disaster relief operations, Jusoh et al. (2024) examined the link between logistics preparedness and humanitarian operations performance in Malaysia. The authors utilized resource-based and stakeholder theories. The study aimed to provide insights into this link as perceived by humanitarian organizations. On the other hand, Shakibaei et al. (2024) developed a multi-objective model for post-disaster relief, focusing on minimizing social dissatisfaction, economic costs, and environmental damage. Their case study of an earthquake in Haiti validated the model's effectiveness in optimizing relief operations. These studies collectively emphasize the critical role of logistics preparedness in enhancing the efficiency and effectiveness of humanitarian supply chains and disaster relief efforts.

### a) Resilient Disaster Relief Operations

The findings from Table 8 below indicate that organizations involved in disaster relief operations demonstrate a relatively strong capacity for resilience. The mean values across all six variables range from 3.88 to 4.11, suggesting that most respondents perceive their disaster relief operations as effective. Specifically, DRO1 (M = 4.00, SD = 0.81) and DRO4 (M = 4.11, SD = 0.82) show the highest levels of agreement, implying that key aspects of resilience, such as adaptability and responsiveness, are well-integrated into relief efforts. Moreover, the moderate standard deviations indicate a reasonable level of consensus among respondents. However, DRO2 (M = 3.88, SD = 0.86) and DRO6 (M = 3.95, SD = 0.96) exhibit slightly lower means, suggesting that some areas of disaster relief operations may still require improvement, particularly in ensuring consistency and efficiency in response mechanisms.
These results suggest that organizations should continue to enhance their disaster relief frameworks by strengthening coordination, improving information flow, and leveraging technology for rapid response. The negative skewness values across all variables indicate that most respondents provided ratings on the higher end of the scale, further supporting the perception of overall effectiveness in resilient disaster relief operations. Additionally, the kurtosis values, ranging from 1.04 to 1.50 as presented in Table 9 below, suggest a relatively normal distribution of responses, confirming the reliability of the data. To further improve disaster resilience, organizations should focus on refining supply chain agility, fostering collaborative partnerships, and implementing continuous monitoring mechanisms to address potential vulnerabilities in relief operations.

Table 8: Descriptive Statistics on the level of agreement of respondents (N=192)

| Variable | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Timely disaster relief operations are essential for mitigating the immediate impact of disasters (DRO1) | 0 (0%) | 4 (2.0%) | 41 (20.3%) | 78 (38.6%) | 69 (34.2%) |
| Rapid response protocols help humanitarian organizations initiate relief efforts quickly (DRO2) | 0 (0%) | 5 (2.5%) | 41 (20.3%) | 76 (37.6%) | 70 (34.7%) |
| Efficiency in disaster relief operations optimizes the use of limited resources (DRO3) | 0 (0%) | 8 (4.0%) | 44 (21.8%) | 107 (52.9%) | 33 (16.3%) |
| Streamlined resource allocation and distribution increase operational efficiency (DRO4) | 0 (0%) | 7 (3.5%) | 37 (18.3%) | 105 (51.7%) | 43 (21.2%) |
| Agility in disaster relief operations allows organizations to adapt quickly to changing conditions (DRO5) | 0 (0%) | 3 (1.5%) | 39 (19.2%) | 107 (52.7%) | 43 (21.2%) |
| Flexible and adaptive response strategies enhance the resilience of disaster relief operations (DRO6) | 0 (0%) | 3 (1.5%) | 29 (14.3%) | 112 (55.4%) | 48 (23.8%) |

Source: Data from Survey (2024)

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Table 9: Descriptive Statistics and Normality Testing for Resilient Disaster Relief Operations (N=192)

| Item | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|
| DRO1 | 4.00 | 0.81 | 0.656 | -1.05 | 1.50 |
| DRO2 | 3.88 | 0.86 | 0.739 | -0.98 | 1.35 |
| DRO3 | 4.06 | 0.90 | 0.810 | -0.98 | 1.25 |
| DRO4 | 4.11 | 0.82 | 0.673 | -1.08 | 1.37 |
| DRO5 | 4.09 | 0.92 | 0.846 | -0.91 | 1.18 |
| DRO6 | 3.95 | 0.96 | 0.922 | -0.87 | 1.04 |

Source: Data from Survey (2024)

Logistics preparedness is defined as the proactive planning and readiness of an organization to handle potential disruptions or changes in logistics operations effectively. It involves development strategies, resources, and systems to ensure the effective flow of goods, information, and services, even in the face of emergencies or unexpected events, like natural disasters, supply chain disruptions, or sudden demand fluctuations. It includes risk assessment, contingency planning, supplies management, alternative distribution efforts, and communication protocols to minimize delays and stabilize operational efficiency. By being prepared, organizations can respond swiftly to challenges, ensuring resilience and minimizing the impact on the supply chain (Jahre et al., 2016; Listou, 2015; Vornanen et al., 2016). In this specific study, the focus was given on preparedness in terms of logistics, financial resources, human resources, and physical resources. This focus was in accordance with the literature by Jusoh et al. (2024).

Logistics preparedness is explained to be very crucial for effective disaster relief operations. In literature, for instance, from Kovács & Spens (2007), the authors proposed a framework distinguishing between actors, phases, and logistical processes in disaster relief operations; they highlighted the unique characteristics of humanitarian logistics. Altay et al. (2009) identified four stages of disaster relief logistics management. The authors emphasized the importance of strategic planning in supplier selection and the related communication protocols. Jahre et al. (2016), on the other hand, addressed the lack of a unified understanding of logistics preparedness across organizations and academic research, proposing a definition and framework to improve visibility and knowledge in this area. The Contribution from the literature stresses the need for better planning and preparedness in humanitarian logistics, drawing parallels with commercial logistics while recognizing the distinct challenges of disaster relief. They also emphasize the importance of empirical research in supporting theoretical frameworks and improving practical applications in the field. The literature ( i.e, Negi, 2022; Negi, 2020; Shafiq and Soratana, 2019; Spens and Kovacs, 2017; Maghsoudi and Moshtari, 2020) has demonstrated that logistics preparedness affects operational success of disaster relief operations. The current study addressed this latter assumption and revealed that logistics preparedness considerably influences disaster relief operations (DROs) in terms of Timely DROs, Efficiency of DROs, and Agility of DROs.

The findings of this investigation are consistent with stakeholder theory and Resource Orchestration Theory (ROT). Stakeholder theory emphasizes the important role of combining efforts and interests to absorb the shocks once the disaster strikes (Fontaine, 2006). This theory goes to the root of stakeholders pooling the necessary resources that should be aimed at smoothing disaster relief operations. Disasters significantly affect the normal functioning of the given society and definitely affect the normal stakeholder operations (Freeman, 2010; Gunasekaran et al., 2018). Preparedness in terms of the joint effort of stakeholder resources could help to alleviate the disastrous event. The interest of humanitarian organizations is to alleviate the suffering of the affected population; sharing of resources in some situations could assist in ensuring the effectiveness of relief operations. By aligning the interests of these stakeholders, the theory ensures that logistics preparedness benefits everyone involved and fosters effective coordination. This approach, which emphasizes value creation and stakeholder relationships, enhances resilience and ensures a timely and efficient disaster response (Freeman et al., 2004; Sachs & Rühli, 2011; Mitchell et al., 1997). Resource orchestration theory (RO), according to Sirmon et al. (2007, 2011), is presented as a rich theoretical foundation combining the resource-based view theory and dynamic capability view theory into one theoretical framework for the purpose of overcoming the constraints addressed by each. According to Malik et al. (2021), the complementarities of the resources and the efficiency of a business organization in orchestrating the resources, both inside and outside of organizational boundaries, determine the capability in the creation of the synergistic effect.

This study's findings are consistent with the findings in a study by Zain et al. (2023), who investigated Humanitarian logistics in disaster preparedness, a case study of monsoon relief distribution for Pulau Redang, Terengganu. Humanitarian logistics preparedness significantly enhances resilient disaster relief operations by ensuring timely and effective aid distribution. The study highlights that strategies such as information gathering, prepositioned supplies, and strong coordination among logistics agencies are crucial. These measures enable

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quick and efficient delivery of assistance to disaster-affected communities, particularly in remote areas like Pulau Redang during the monsoon season. Local community involvement further strengthens these efforts, ensuring that the needs of the population are met promptly and effectively. The findings are also consistent with those of Seraji et al. (2021), who conducted a study on an integrative location-allocation model for humanitarian logistics with distributive injustice and dissatisfaction under uncertainty. The study by Seraji et al. (2021) demonstrated that Humanitarian logistics preparedness significantly enhances resilient disaster relief operations by integrating planning and execution across different phases, minimizing gaps in relief provision. By addressing operational, distributive injustice, and dissatisfaction costs, effective preparedness ensures timely and equitable assistance to affected populations, ultimately improving overall disaster response outcomes.

The current study found that logistics preparedness affects resilience of disaster relief operations in terms of Timely DROs, Efficiency of DROs, and Agility of DROs. Preparedness in the current study was viewed based on financial resources, logistics, human resources, and logistics' physical resources preparedness. Further to the above literature, Ghasemi et al. (2022) found that this sort of humanitarian logistics preparedness significantly enhances resilient disaster relief operations by ensuring efficient resource allocation and timely response. The paper emphasizes a multi-objective optimization model that minimizes costs, unsatisfied demands, and evacuation failures, addressing both pre- and post-disaster scenarios. By integrating strategic and operational decisions, the model improves the effectiveness of shelter locations, relief distribution, and route planning, ultimately leading to better outcomes for affected populations during uncertain disaster situations. Similar findings are reported by Connelly et al. (2016), who found that humanitarian logistics preparedness significantly enhances resilient disaster relief operations by ensuring effective resource allocation and prioritization among logistics investments. The Integration of scenario analysis and multicriteria decision analysis allows emergency management agencies to address uncertainties and performance criteria related to population behaviors and environmental changes. This approach aids in developing agile and resilient supply chains, particularly benefiting underrepresented populations, as demonstrated in preparedness initiatives for first-responder agencies in Rio de Janeiro, Brazil.

When humanitarian logistics preparedness is enhanced, it is likely to increase effectiveness and efficiencies in disaster relief operations. Preparedness can be improved from sustainable and flexible financial resource allocation, investing in financial risk management and contingency planning, ongoing training and capacity-building initiatives for logistics personnel, strategic recruitment and efficient deployment of skilled Personnel, adequate prepositioning and maintenance of essential physical resources, and from effective resource management and sustainable practices in logistics assets support continuity and adaptability across various disaster scenarios. As observed by Moonesar (2025), humanitarian logistics preparedness significantly enhances resilient disaster relief operations by ensuring effective resource allocation and tailored relief strategies. Predictive analytics and data-informed insights facilitate readiness, rapid responses, and recovery, as exemplified by partnerships in the International Humanitarian City. These collaborations prevent redundancy and speed up response times, ultimately aligning resources with on-ground needs. By fostering knowledge transfer and adaptability among stakeholders, preparedness strengthens the overall capacity to respond effectively to crises, thereby reducing adverse public health impacts. This is also supported by Osumo & Omwenga (2024), who highlight that humanitarian logistics significantly impact emergency response capabilities in disaster relief operations. It found a strong positive association ($\beta = 0.732$, $p < 0.001$) between logistics management practices and effective emergency response. This indicates that enhancing logistics preparedness, including resource allocation and strategic alliances, is crucial for resilient disaster relief operations. By prioritizing logistical development, humanitarian organizations can improve their response outcomes, ultimately leading to more effective disaster management in Kenya.

The findings of this specific study are consistent with those of Jusoh et al. (2024). The paper explores the relationship between logistics preparedness and the performance of humanitarian operations, emphasizing that effective logistics preparedness enhances the resilience of disaster relief operations. Examining the perspectives of humanitarian organizations in Malaysia highlights that well-prepared logistics can significantly improve response times and resource allocation during disasters, ultimately leading to more effective and efficient relief efforts. This preparedness is crucial for ensuring that humanitarian organizations can meet the challenges posed by disasters effectively. Also supported by Aghsami et al. (2024), humanitarian logistics preparedness significantly enhances resilient disaster relief operations by optimizing resource allocation and minimizing response times. The study emphasizes the importance of pre-disaster planning within organizational contexts, utilizing a mixed-integer nonlinear model to address logistical challenges. By

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incorporating operations centers, external stakeholders, and medical facilities, the model aims to reduce costs associated with untreated injuries and delays in relief distribution, ultimately improving the effectiveness and efficiency of disaster response efforts. Furthermore, Mazloum et al. (2024) demonstrated that humanitarian logistics preparedness significantly enhances resilient disaster relief operations by ensuring adequate capacity and strategic location of medical centers, effective distribution of relief supplies, and proper equipment availability. The study emphasizes that pre-disaster efforts, such as the establishment of Temporary Medical Centers (TMCs) and procurement planning, are crucial for optimizing response during the post-disaster phase. By analyzing casualty types and transportation modes, the proposed model aids in making informed decisions that improve overall operational efficiency and effectiveness in disaster scenarios.

### b) Findings from the Interviews on the Logistics Preparedness Variable

With this specific objective, two themes were established. The first theme was related to logistics preparedness measures. The second theme was related to training and simulation exercises' Contribution to logistics preparedness. The measure that takes much consideration for preparedness is training the logistics teams and thinking of the ways to facilitate communication with teams, which, most of the time, is a challenge. Most of the respondents emphasized the importance of having specialized information systems for communication and how to go about the prepositioning of essential supplies and resources in a disastrous situation. Physical resources, financial resources, and human resources have been the most contributing issues in the case of logistics preparedness. Some of the experts in humanitarian logistics and disaster relief operations narrated that.

> *"……. effective disaster operations rely on several key preparedness measures. One of them is the prepositioning of essential supplies and resources, like food supplies and medicine, which need to be in strategic locations to ensure immediate availability when disaster strikes. The other thing is to develop a strong supply chain network, like establishing partnerships with local and international suppliers, which will enhance flexibility and response speed. On the other hand, adopting real-time tracking and automated inventory systems and conducting regular training and simulation exercises for logistics teams ensures readiness and efficiency in emergency situations.*

Another informant added that.

> *"…….our systems for relief operations as a nation, from my experience, need collective efforts, from specialized humanitarian organizations to the government agencies, on this I think we need the establishment clear communication channels and coordination mechanisms among the stakeholders, including government agencies, other NGOs, and private sector partners, this will aid for seamless and effective response."*

In training and simulation exercises, it was revealed that most of the teams responsible for rescues and field operations need continuous training in these areas. Special training is conducted to train field officers on the basic operations for rescues and preparedness when a disaster strikes. It was also revealed that the training is mostly conducted for the most routine emergencies, like rescues in floods, fire eruptions, hunger, pandemics, and accidents. It was revealed that some training on these aspects needs to consider the local volunteers and local communities. In this regard, the respondents reported the following:

> *"…. collaborating with local communities plays a crucial role in enhancing the efficiency of disaster relief logistics. The local knowledge and networks help responders navigate affected areas quickly and identify priority needs."*

It was revealed that regular training and simulation exercises are essential for enhancing logistics preparedness for any humanitarian organization like ours. It was found that training and simulation exercises help in building the capacity of logistics teams, and they improve their ability to respond quickly and efficiently during emergencies. These specific exercises also help in identifying the gaps in response strategies, allowing for continuous improvement in logistics coordination, in allocating resources, and in communication. One of the respondents added that.

> *"…..instituting training to the workforce continuously, can enhance collaboration among stakeholders, ensuring that all necessary parties, from supply source to field teams, understand their roles and responsibilities"*

In this regard, it was also found that in the course of implementing these exercises, there are also challenges. The interview revealed that budget constraints often limit the frequency and scale of the intended training programs. Another challenge is the availability of staff, as operational demands may prevent full participation.

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Another issue communicated was on ensuring realistic simulation scenarios that truly reflect potential disaster conditions. One of the respondents here narrated that:

> *"……despite the challenges, we try continuously to strive to integrate training into our disaster logistics strategy, we are looking forward to strengthening overall disaster preparedness and our response capabilities, but we also need to strategize on how to improve collaboration with other humanitarian organizations."*

# 5. Recommendations and Conclusion

The findings of this study demonstrated that the humanitarian logistics preparedness is significantly related to resilient disaster relief operations. In this context, humanitarian logistics preparedness is a significant predictor of resilient disaster relief operations. This portrays that it is crucial for the humanitarian organizations and agencies to invest in strengthening all the necessary aspects of logistics preparedness. The humanitarian logistics preparedness may be strengthened from ensuring sustainable and flexible financial resource allocation (which is critical for ensuring continuous readiness and rapid response), ensuring that there is adequate investment in financial risk management and preparation of a wide contingency planning (which is likely to enhance the resilience and sustainability of logistics operations during unpredictable crises), instituting ongoing training and capacity-building initiatives to humanitarian operations practitioners ( which is crucial for maintaining a skilled and adaptable workforce in emergency situations), and ensuring that there's strategic recruitment and efficient deployment of skilled Personnel ( which will enable rapid mobilization and strengthen the preparedness). It is also essential to ensure that there is adequate prepositioning and maintenance of essential physical resources used in disaster operations (such as vehicles and rescue equipment, as this will enhance operational readiness in disaster response, and lastly to ensure effectiveness in resource pooling and management, and that there are sustainable practices in logistics assets to support continuity and adaptability across various disaster scenarios. With this, the study suggests that the departments and units responsible for disaster relief operations and other humanitarian organizations (local and international agencies) should emphasize and strategize logistics preparedness since this is one of the crucial aspects to ensuring resilience of operations once a disaster strikes.

## 5.1 Contribution of the Study

Based on the findings, this study is found to make contributions to theory, knowledge, policy, and operational practices.

### 5.1.1 Contribution to Theory

The findings of this current study contribute significantly to the theoretical understanding of logistics preparedness and resilient disaster relief operations. Reflecting on the resource orchestration theory and stakeholder theory, this study reinforces the idea that tangible and intangible logistics resources are critical for effective humanitarian operations. Resource pooling and orchestrating the resources from the stakeholders are essential for resilient disaster relief operations. The understanding in this study enhances theoretical frameworks in humanitarian logistics by emphasizing the interplay between resource orchestration and strategic responsiveness. Future theoretical models in this context may benefit from incorporating these specific preparedness indicators as integral to resilience outcomes

### 5.1.2 Contribution to Knowledge

In a developing country context, this current study makes a notable empirical knowledge contribution by quantitatively establishing the influence of logistics preparedness on resilient disaster relief operations. Reflecting on the primary data of 192 respondents and validated by rigorous statistical analysis, this study presents a clear linkage between six logistics preparedness indicators and the operational effectiveness of disaster relief efforts. As the findings of this study reveal that preparedness in financial, human, and physical logistics resources significantly enhances resilience, with up to 75% of the variation in resilience being explained by these factors, such granular evidence enriches existing knowledge by demonstrating the logistics capabilities impacting resilient disaster relief operations. This study extends existing knowledge by emphasizing the need for structured, resource-driven logistics planning as a foundation for achieving resilience in disaster management.

### 5.1.3 Contribution to Policy

The findings of this study also have implications for policymakers: the Government of Tanzania's Prime Minister's Office has in place a National Disaster Management Strategy (2022 – 2027). This strategy has

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been prepared and developed with the understanding that all development in the country, achievements, and initiatives need to be protected from the impact of disaster events. In this context, the Government is aiming to ensure that disaster risk reduction is well stressed and is an integral part of national policies and programs. This study will aid in considering holistic approach towards disaster risk management and humanitarian services, where in this, the emphasis has been given on working together with all stakeholders to develop and implement strategic, scientific and innovative partnerships for community resilience, which is also a core theme in the strategy and can aid in the preparation of the next Prime Minister's Office National Disaster Management Strategy.

#### 5.1.4 Contribution to operational Practices

On the other hand, these study findings also have a wide implication for the management of disaster operations coordination departments, humanitarian organizations, and agencies. The study in one instance challenges the first responders and national disaster relief operations protocols and red tape mechanisms used. In this regard, the study demonstrates the need to harmonize the protocols and red tape and proposes having operating procedures and necessitating structuring mechanisms or a framework to articulate that any unit responsible for relief service, in proximity to the affected area, be a first responder backing up the community efforts and participation. The findings of this study suggest the need for the management of humanitarian organizations to ensure that all logistical impediments are continuously addressed and improved, and that the necessary partnerships with other organizations and suppliers are properly proactively structured and established.

### 5.2 Recommendations of the study

#### 5.2.1 Theoretical Recommendations

The findings underscore the importance of logistics preparedness in enhancing resilience. Based on these insights, the study recommends the following theoretical advancements:

First, future theoretical discussions should integrate a broader range of stakeholders, including the local communities, private sector entities, technology providers, and healthcare units, to better understand their influence on resilience. Secondly, future research should refine ROT in order to encompass dynamic resource allocation models that adapt to changing disaster environments. Thirdly, future theoretical work should focus on further developing frameworks that assess the efficiency of multi-actor coordination mechanisms and the establishment of a comprehensive model to link logistics preparedness to resilience outcomes. Fourth, with the increasing role of digital tools in humanitarian logistics, theoretical frameworks should also integrate the influence of technologies such as blockchain, artificial intelligence, and real-time tracking on disaster relief resilience.

#### 5.2.2 Empirical Recommendations

Empirically, the current study was motivated by a lack of empirical studies linking humanitarian logistics preparedness and resilient disaster relief operations. However, the current study does not have the self-sufficiency to explain humanitarian logistics preparedness and resilient disaster relief operations in all contexts, and this is due to its conceptual and methodological limitations. Therefore, the study recommends that more studies be conducted using similar or other variables in different contexts.

Based on the empirical findings of this study linking humanitarian logistics preparedness and resilient disaster relief operations, several actionable recommendations are proposed to enhance the effectiveness of humanitarian logistics and resilience. These recommendations are dedicated to humanitarian organizations, policymakers, and stakeholders involved in disaster response and supply chain management. First, it will strengthen supply chain coordination and Integration. The study highlighted the role of preparedness among humanitarian actors, including government agencies, non-governmental organizations (NGOs), and private sector partners. Second: to enhance infrastructure and Logistics capacity. A key constraint identified in the current study is the inadequacy of infrastructure, which hampers effective disaster response. Third: to leverage technology and digital innovations. The adoption of digital tools and emerging technologies such as Geographic Information Systems (GIS), artificial intelligence (AI), and blockchain can significantly improve humanitarian logistics. Fifth: to continuously and strategically build capacity and train humanitarian Personnel. The research findings emphasize the need for continuous capacity building among humanitarian workers and practitioners for basic and specialized rescue operations. Sixth: to develop sustainable and localized supply chains. In order to improve resilience, humanitarian organizations should engage local suppliers and communities in their supply chains. Seventh: to depend mostly on our national plans, building national capabilities, and strengthening policy frameworks and regulatory support. The study underscores the role of government policies in facilitating

humanitarian logistics. Eighth: to promote community engagement and public awareness. Empirical and practical evidence suggest that community involvement plays a critical role in disaster response and recovery. Ninth: to enhance financial and resource mobilization strategies. Funding constraints remain a significant challenge in humanitarian logistics.

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# Investigating The Role of Green Logistics Practices in Reducing Nonrenewable Energy Consumption

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## Abstract

***Purpose**: The purpose of this paper is to highlight the significance of green logistics practices in minimizing nonrenewable energy usage, with a specific focus on the mediating role of B2B customers' purchasing intentions.*

***Design/methodology/approach:** This study employs qualitative research, starting with a Systematic Literature Review (SLR) to examine green logistics practices in reducing nonrenewable energy use. Semi-structured interviews with ten Egyptian petroleum logistics experts validate and refine a research framework derived from the SLR. The research is theoretically grounded in the Resource-Based View (RBV), framing green logistics as strategic organizational capabilities. Additionally, Institutional Theory is used to understand the role of external pressures shaping B2B purchasing decisions.*

***Findings:** The study identified key green logistics themes, including green purchasing, transportation, and reverse logistics, highlighting Egypt's efforts to reduce greenhouse gas emissions through public-private collaborations. Despite progress, challenges like weak infrastructure and low awareness persist. A conceptual framework was developed, showing how green logistics practices influence purchasing intentions and energy reliance reduction, offering insights for policymakers and organizations.*

***Theoretical Contribution:** This study advances the application of the Resource-Based View (RBV) and Institutional Theory within the context of green logistics in emerging markets. Integrating both theories offers a deeper understanding of how internal capabilities and external institutional pressures jointly shape sustainable purchasing behavior in B2B settings. The study also contributes to the literature by developing a conceptual framework linking green logistics practices to reduced nonrenewable energy dependence through B2B customer engagement.*

***Practical Contribution:** The findings provide actionable insights for policymakers, logistics managers, and stakeholders in the petroleum sector. By identifying critical barriers such as infrastructure limitations and low awareness, the study suggests targeted strategies for promoting green logistics. Moreover, the conceptual framework can serve as a roadmap for organizations aiming to align sustainability goals with customer expectations, thereby supporting Egypt's broader environmental and energy transition objectives.*

***Keywords:** Sustainable Energy, Green Logistics Practices, B2B Purchase Intention, Nonrenewable Energy, Resource-Based View, Institutional Theory*

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# Introduction

Environmental concerns about human activity's impact on the planet have gained widespread attention across media, governments, academia, and the public. Businesses increasingly adopt green logistics practices to enhance sustainability performance, gain competitive advantages, and meet stakeholder demands for accountability (Abd Elbarky et al., 2022; Chen et al., 2023). Green Logistics Practices (GLPs) aim to balance economic, environmental, and social factors by integrating eco-friendly ideas into logistics to reduce environmental harm, conserve resources, and improve business performance (Hashmi, 2022; Agyabeng-Mensah et al., 2022; Cheng et al., 2024).

The rising global demand for eco-friendly practices and products drives businesses to adopt green logistics for reduced waste, energy use, and environmental harm, gaining a competitive edge and improving reputation (Alsuraihi et al., 2022). Green practices involve challenges such as varying objectives, technological issues, and budget constraints, necessitating collaboration with supply chain partners (Pakurár et al., 2020). Energy, a cornerstone of economic development, relies on both renewable and nonrenewable resources. Fossil fuels, though vital, contribute to the climate.

Change and are depleting, prompting urgent shifts toward sustainable energy alternatives (Singh et al., 2019; Perissi et al., 2023).

Purchase intention, a key aspect of consumer behavior, reflects an individual's likelihood of buying a specific product, influenced by factors such as needs, attitudes, and perceptions (Kytö et al., 2019). Green purchasing emphasizes eco-friendly procurement to minimize harm to health and the environment (Nur et al., 2021). While interest in the impact of Green Logistics Practices (GLP) on reducing nonrenewable energy use is growing, research gaps remain. Studies have yet to fully explore how GLPs optimize energy use and influence renewable adoption, requiring deeper insights into their effectiveness and purchase-related factors (Khan et al., 2022; Leung et al., 2023).

This research advances green logistics practices while emphasizing the mediation role of purchase intention drivers to promote sustainable development in critical regions. It identifies key factors impacting the reduction of nonrenewable energy use through these drivers. The study is structured as follows: introduction, literature review, research methodology, findings and discussion, and conclusion.

# Literature Review

The escalating global concern for environmental sustainability has prompted organizations to adopt eco-friendly practices across their supply chains. Green logistics, a strategic approach that integrates environmental considerations into logistics operations, has emerged as a crucial component of sustainable business practices. This literature review delves into the intricate relationship between green logistics practices, purchasing intention drivers, and nonrenewable energy consumption.

## Green Logistics Practices

Green logistics practices are management measures aimed at reducing air pollutants, CO2 emissions, misuse of resources, and improper waste disposal while promoting environmental sustainability (Popescu et al., 2024). These practices ensure efficient goods and information flow to meet customer needs and foster social development (Vienažindienė et al., 2021; Huong et al., 2024). Businesses adopt green logistics to fulfill environmental obligations, gain a competitive edge, attract new clients, and achieve social and financial benefits (Karaman et al., 2020; Agyabeng-Mensah & Tang, 2021). Green logistics integrates environmental goals into business decisions, addressing social, economic, and environmental challenges while maintaining profitability and efficiency in logistics operations (Khan et al., 2019; Vienažindienė et al., 2021; Roy and Mohanty, 2024).

## Purchase Intention

Purchase intention reflects consumer preferences shaped by experiences, attitudes, and beliefs, often serving as a predictor of actual purchasing behavior (Zhuang et al., 2021; Susilo et al., 2024). Green purchase intention, the likelihood of buying eco-friendly products, is influenced by factors such as values, attitudes, motivation, knowledge, and customer satisfaction (Abd Elbarky et al., 2022). Consumers with greater environmental awareness are more likely to adopt sustainable purchasing patterns (Cui et al., 2024). Behavioral goals, informed by self-perception and perceived values, play a key role in driving the shift toward eco-friendly consumption (Tavitiyaman et al., 2024).

## Nonrenewable Energy Source

Nonrenewable energy sources like coal, oil, and natural gas account for 80% of global energy consumption, but their environmental and societal impacts are severe (IEA, 2022). Fossil fuel combustion is the primary

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source of greenhouse gas emissions, driving climate change and causing rising temperatures, extreme weather, and biodiversity loss (IPCC, 2021; NASA, 2022). Extraction methods such as fracking and deep-sea drilling harm ecosystems, pollute water, and erode soil, while spills and runoff cause long-lasting damage (EPA, 2021; WWF, 2022). Reliance on these fuels exacerbates socioeconomic inequalities and economic instability, highlighting the urgent need for investments in renewable energy and sustainable policies (UNDP, 2020; UNEP, 2020).

### The Relationship between Green Logistics Practices and Purchase Intentions

The relationship between Green Logistics Practices (GLPs) and purchase intentions is crucial for promoting eco-friendly consumption (Lee et al., 2021). Increased consumer awareness of environmental impacts directly influences their buying behavior (Xue et al., 2022). Integration of green logistics enhances sustainability commitment, fostering consumer trust and loyalty (Zhu et al., 2021). Studies show that green supply chain practices in industries like fast food (Rehmani & Siddiqui, 2019) and green environmental practices, including attitudes, marketing, and customer value, significantly influence purchase intentions in multiple countries (Ahmed et al., 2024).

In Egypt, Abd Elbarky et al. (2023) found no significant direct relationship between green supply chains and purchase intentions, but green perceived quality and customer satisfaction significantly influenced this connection. Rahman et al. (2021) highlighted the mediating role of trust and perceived value in linking Green Logistics Practices (GLPs) to purchase intentions. Furthermore, Nguyen et al. (2023) emphasized that green stocking practices, which focus on efficient inventory management and waste reduction, help build a positive corporate image and encourage eco-conscious buying behavior.

Several factors influence the relationship between Green Logistics Practices (GLPs) and purchase intentions. Green packaging innovations, such as biodegradable and reusable materials, attract environmentally conscious buyers by reducing waste (Chen et al., 2022). Smart green transportation, which minimizes carbon emissions through optimized networks and alternative

Energy significantly impacts purchase intentions by showcasing a company's commitment to environmental responsibility (Tang & Tong, 2020). Additionally, end-of-life practices focused on recycling and reusing products align with consumer sustainability values, influencing their purchasing decisions (Kumar & Kumar, 2023).

### The Relationship between Purchase Intentions and Nonrenewable Energy Sources

Purchase intentions play a crucial role in reducing the consumption of nonrenewable energy sources (NRES) as individuals and organizations increasingly opt for renewable alternatives due to heightened environmental awareness, regulatory pressures, and societal demand for sustainability (Ali & Naushad, 2023). Nazir and Tian (2022) demonstrated that renewable energy significantly influences consumer attitudes, using the Unified Theory of Acceptance and Use of Technology as the conceptual framework. Their study, based on structured questionnaires from 497 respondents in Pakistan, found a strong positive correlation between purchase intention for renewable energy technology and factors like cost, ease of use, relative advantage, social media exposure, and awareness.

In the Jordanian context, Almrafee and Akaileh (2024) studied factors influencing consumers' intentions to purchase renewable energy, based on an online poll of 428 Jordanians who do not currently use renewable energy. They found that attitudes, subjective norms, perceived price, knowledge, and perceived behavioral control significantly affect purchase intentions. Similarly, Ajzen (2020) emphasized that attitudes, subjective norms, and perceived behavioral control, as outlined in the Theory of Planned Behavior, shape purchase intentions. Consumers with strong pro-environmental attitudes are more likely to reduce their reliance on nonrenewable energy and invest in renewable solutions like solar or wind power (Rahim et al., 2022).

Malik et al. (2020) explored the relationship between renewable energy products (like solar panels) and consumer purchase intentions, finding that product-related knowledge, environmental concerns, and perceived risks influence purchasing decisions. Zhou et al. (2021) highlighted the importance of corporate purchase intentions in reducing reliance on nonrenewable energy sources, as businesses incorporating sustainability into their procurement strategies shift toward green energy. However, Tang et al. (2020) pointed out that challenges such as limited renewable energy infrastructure and a lack of awareness in some regions still hinder purchase intentions, perpetuating dependence on nonrenewable energy sources.

### The Relationship between Green Logistics Practices and Nonrenewable Energy Sources

Environmental sustainability is hindered by logistics operations' dependence on fossil fuels and nonrenewable energy sources. "Green logistics" aims to balance economic efficiency with environmental

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preservation by reducing environmental externalities (Khayyat et al., 2024). Kim et al. (2024) explored the connection between green logistics practices (GLPs) and nonrenewable energy sources using Data Envelopment Analysis-Slack-Based Measure (DEA-SBM) and Tobit

Regression. Their findings showed that GLPs are closely linked to nonrenewable energy sources, with ESG reports and government policies influencing the financial efficiency of logistics companies.

Osman et al. (2022) explored the impact of fossil fuel-free fuels as a green logistics practice (GLP), finding that green freight transport is growing in popularity, with customers willing to pay more for it. However, public regulations had minimal influence, as internal initiatives and corporate stakeholders drove the development of green logistics services. Khayyat et al. (2024) studied the adoption of green logistics technology and information systems in Saudi Arabia, highlighting the significance of nonrenewable energy sources. Their findings showed strong environmental awareness among stakeholders and a business culture supportive of sustainability, with widespread recognition of the benefits of green logistics technologies.

Aytekin et al. (2024) identified the most sustainable approach for logistics organizations and explored green energy challenges, employing a hybrid T-spherical fuzzy (T-SF) methodology. The study found that "energy security" is the most critical green energy component for logistics firms, with the socially beneficial services supply strategy being the most effective sustainable approach. Diaz et al. (2021) investigated the relationship between green logistics and renewable energy in La Guajira, Colombia, where off-grid sustainable energy generation systems are being implemented to reduce reliance on fossil fuels and improve electrical delivery.

## Developing a Framework

The researcher develops a framework connecting Green Logistics Practices, Nonrenewable Energy Usage, and Purchase Intentions by synthesizing findings from previous studies. This framework aims to integrate relevant measures, variables, and models based on the relationships discussed in the literature. A systematic literature review is identified as the most appropriate approach for creating this linking framework.

## Systematic Literature Review

To conduct a systematic literature review, the researcher collected information from various sources, including scientific publications, prior studies, books, periodicals, dissertations, and reports on sustainable smart ports, specifically focusing on Green Logistics Practices, Non-renewable Energy Usage, and Purchase Intentions. The review process involved a detailed search across academic databases like Scopus and Web of Science, targeting studies published between 2011 and 2024.

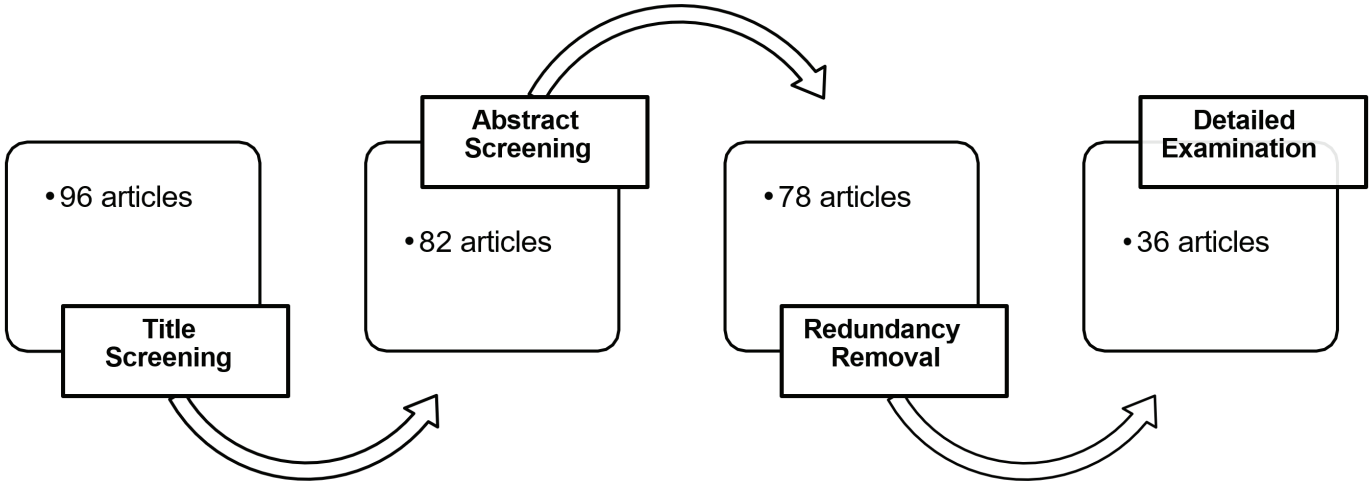


Figure 1: Review Process Scheme (by researcher)

Figure (1) outlines the process used to review 96 works: identifying the research scope, selecting related studies, assessing their quality, extracting and tracking data, integrating studies, and adjusting sources. Most of the authors were affiliated with higher education institutions, as shown in Table 1. The literature selection was based on keywords used to search online databases. The sources were chosen for their ability to describe the relationships between Green Logistics Practices, Nonrenewable Energy Usage, and Purchase Intentions. Bibliometric maps were created using VOS viewer software version 1.6.11.

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Table 1: Research Steps

| Stage | Sub-stage | Description | Number of records |
|---|---|---|---|
| **Step 1** | Identification of research field | Initially, a title filtering procedure was applied to all retrieved papers to find publications about nonrenewable energy, green logistics practices, and purchasing intentions. To find articles related to these-subjects, it was necessary to skim the titles of the articles. | 201 |
| | Keywords | Filter the database:*'Green logistics practices', 'Nonrenewable energies', 'Sustainable Energy', and 'Purchase Intentions'* | |
| **Step 2** | Scopus and WOS citation search | 1) Find the research string in the title, Abstract, OR subject terms in databases such as Web of Science, Scopus, Google Scholar, and Springer.<br>2) Search timeline: 2011-2024<br>3) Language: English<br>4) Source type: Academic journals | 96 |
| | Removal and extraction of duplicate records | Duplicate records are eliminated, and citations are extracted to EndNote. | 82 |
| **Step 3** | Redundancy Removal | During the database searches, duplicate entries related to green logistics practices, purchase intentions, and nonrenewable energy were commonly found. These repetitive items were removed to maintain the integrity of the review process. | 78 |
| **Step 4** | Detailed Examination | The remaining 78 articles were carefully reviewed, focusing on key aspects such as nonrenewable energy, purchasing intention, and green logistics practices. This detailed examination aimed to assess.The quality and relevance of each article to the research topics. | 36 |

Systematic Review AnalysisSeveral studies have explored how green logistics practices influence energy consumption. For example, implementing green transportation strategies, such as route optimization and fuel-efficient vehicles, can significantly reduce fuel use and greenhouse gas emissions (Khan et al., 2019). Additionally, efficient inventory management and reverse logistics practices help minimize energy usage in warehousing and transportation (Hyder et al., 2023). The relationship between green logistics practices and nonrenewable energy consumption can be mediated by purchase intention drivers. Research has shown that consumers' environmental awareness, influenced by advertising and education, positively affects their purchasing intentions for green products (Vargas et al., 2021; González-Viralta et al., 2023; Almrafee and Akaileh, 2024; Tavitiyaman et al., 2024). This, in turn, encourages businesses to adopt more sustainable logistics practices.

Table 2 shows the most cited papers relating to the research topic published from 2011 to 2024 based on a search for the terms (Green Logistics Practices, Nonrenewable Energy Usage, and Purchase Intentions) in the WoS and Scopus.

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Table 2: Most Cited Paper, Publication, and JIF

| Year | Title | Authors | Journal | Citations |
|---|---|---|---|---|
| 2019 | Environmental, social, and economic growth indicators spur logistics performance: from the perspective of-South Asian Association for Regional Cooperation countries. | Khan et al. | Elsevier | 266 |
| 2019 | Renewable energy development as a driver of economic growth: Evidence from multivariate panel data analysis. | Singh et al. | mdpi.com | 163 |
| 2019 | From intention to action: Predicting purchase behavior with consumers' product expectations and perceptions, and their individual properties | Kytö et al. | Elsevier | 87 |
| 2020 | Green logistics performance and sustainability reporting practices of the logistics sector: The moderating effect of corporate governance. | Karaman et al. | Elsevier | 234 |
| 2021 | On the factors influencing green purchase intention: A meta-analysis approach. | Zhuang et al. | frontiersin.org | 373 |
| 2021 | The relationship among green human capital, green logistics practices, and green competitiveness, social performance, and financial performance. | Agyabeng- Mensah and Tang | emerald.com | 141 |
| 2021 | Green logistics practices seeking development of sustainability: evidence from Lithuanian transportation and logistics companies. | Vienažindienė et al. | mdpi.com | 73 |
| 2021 | Green supply chain management and its impact on consumer purchase decisions as a marketing strategy: Applying the theory of planned behavior. | Lee et al. | mdpi.com | 38 |
| 2022 | The influence of consumers' purchase intention factors on willingness to pay for renewable energy; mediating effect of attitude. | Nazir and Tian | frontiersin.org | 34 |
| 2023 | Business Performance Through Government Policies, Green Purchasing, and Reverse Logistics: Business Performance and Green Supply Chain Practices. | Hashmi | journal.sagpb.com | 51 |

Systematic Review FindingsThis study aims to expand existing research by analyzing the connections between green logistics practices, nonrenewable energy consumption, and purchase intentions within a specific context. It focuses on key factors that have shown significant effects in previous studies, contributing to both theoretical and practical understanding in sustainability. The major findings and limitations are summarized in Table 3.

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Table 3: Major Findings and Limitations

| Research Area | Study | Major Findings |
|---|---|---|
| Green purchase | Tavitiyaman et al. (2024) | • Although many hotel guests recognize the importance of the environment, other influential factors, such as first-time travel after COVID-19, travel destinations, and purposes of visit, can take precedence in green purchasing decision-making.<br>• Hotel guests may prefer to allocate their funds to food, shopping, and travel activities rather than invest in green hotel products and services.<br>• Although recycling and reuse are encouraged by the Hong Kong government and community, societal norms do not significantly influence people's intentions to make green purchases because they are now commonplace in daily life. To put it another way, the respondents do not rely on their friends and relatives to help them decide which eco-friendly hotels to book. They do not rely on the support of others, but rather on their convictions about eco-friendliness hotel consumption. |
| End-of-life practices | de Campos et al. (2023) | • The research assessed the role that important elements play in the adoption of end-of-life management methods in medicine and how they affect logistical green performance.<br>• A systematic questionnaire was completed by 67 experts who were selected from the public pharmaceutical care procedure. Using partial least squares-structural equation modeling, the gathered data was examined. Eleven of the fifteen hypotheses that were studied were validated by the theoretical structural test.<br>• The findings showed that end-of-life management procedures directly impact logistics green performance. Although there was no moderating influence, the research did establish a clear relationship between the information technology element and the end-of-life management techniques. |
| Green Transportation | Khan et al. (2019) | • The results show a substantial correlation between low-quality transportation-related infrastructure and trade, green energy resources, fuel consumption, carbon emissions, greenhouse gas emissions, health care spending, and political instability in a nation.<br>• Inadequate transportation-related infrastructure leads to increased greenhouse gas emissions and carbon emissions from logistical operations, which not only degrade the environment but also pose health risks to people, such as lung, eye, and asthma illnesses.<br>• Inadequate transportation-related infrastructure and logistics are<br>• Also, a major result of political instability. |
| Green packaging | Karaman et al. (2020) | • In order to reduce energy and material consumption, the industry is under pressure from both local and foreign stakeholders to implement eco-friendly options in the processes of procurement, warehousing, packaging, and delivery.<br>• The idea of "green logistics", which refers to the implementation of eco-friendly procedures across the supply chain, emerged as a result<br>• of these conversations. |
| Green stocking | De Souza et al. (2022) | • Experts ranked 27 green practices and indicators of the created tool using the Analytic Hierarchy Process (AHP) method. The indicators were then standardized to produce a single index of the GL in businesses.<br>• The findings indicate that when businesses approach environmental sustainability, they tend to disregard certain aspects of green logistics, which jeopardizes the advancement of GL. Green stocking, green packaging, and reverse logistics, on the other hand, show the worst outcomes in the green transportation category. |

| | | |
|---|---|---|
| Sectional reverse logistics | Hyder et al. (2023) | • Throughout the supply chain, RL has a substantial financial impact on companies and their suppliers.<br>• Reverse logistics adoption is still in its infancy in developing nations like Pakistan due to several obstacles, such as high adoption costs, a shortage of professionals with the requisite skills, a lack of relevant laws, an unsuitable organizational culture, a lack of human resources, a lack of environmental awareness among stakeholders,<br>• and the lack of community pressure. |
| Purchasing Level of Nonrenewable Energy Sources | Diaz et al. (2021) | • The goal of the study was to enhance the standard of living for members of a vulnerable group that receives just ten hours of power every day.<br>• Over time, investment costs demonstrate considerable profitability. An intriguing idea that starts with renewable energy was produced<br>• by concentrating the project on green logistics. |
| Seasonality | Vargas et al. (2021) | • Several studies proved the profound linkage between seasonality and green purchase intention. The idea of local seasonality offers pertinent data for research on sustainable consumption. However, defining what is local is essential for making effective<br>• use of this idea. |
| Existing customer satisfaction | González-Viralta et al. (2023) | • The findings highlight the significance of green practices in fostering consumer satisfaction and various customer behaviors, including word-of-mouth, loyalty, and readiness to pay more.<br>• Results also demonstrate the beneficial effects of satisfaction on word-of-mouth, loyalty, and readiness to spend more.<br>• These findings also offer factual proof of how green practices impact the grocery business and, consequently, its progress toward more sustainable management. |
| Customers' demographics | Almrafee and Akaileh (2024) | • In order to ascertain whether there are any statistically significant variations between the demographic features of customers and their intentions to purchase renewable energy (solar panels), demographic data are offered as control variables. Demographics were broken down into four aspects (education, income, age, and gender).<br>• Customers' purchase intention toward renewable energy (solar panels) is influenced by the remaining demographic factors (control variables), except for gender, according to the results of the T-test and one-way ANOVA. |
| Advertising | Tavitiyaman et al. (2024) | • Many hotels use social media and internal ads to inform visitors about their eco-friendly operations, which may increase the chance they will purchase. Conversely, subjective norms have little effect on consumers' intentions to book an eco-friendly hotel. |

Green logistics techniques, such as green purchasing, transportation, packaging, and reverse logistics, are effective in reducing nonrenewable resource consumption and enhancing sustainability. Purchasing intention plays a significant mediating role in this relationship. This review suggests developing a composite index to measure GLP sustainability, with a focus on regions like Egypt, requiring further research and regional policies.

## Research Variables

The current study develops a theoretical model focusing on Green Logistics Practices (GLP), defining its dimensions and exploring their impact on reducing nonrenewable energy usage. It highlights the mediating role of purchase intention drivers, which has been underexplored in prior research. The theoretical framework illustrates the relationships between GLP

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dimensions, purchase intentions, and nonrenewable energy consumption, with various research variables considered. The research variables considered are as follows:

Independent Variable: Green Logistics Practices and its dimensions (Green purchase, End -of -Life practices, Green Transportation, Green packaging, Green Stocking, Sectional, Reverse Logistics).

Dependent Variable: Purchasing Level of Nonrenewable Energy Sources.

Mediator Variable: Purchasing Intention.

Therefore, the current research framework could be expressed using the following figure.

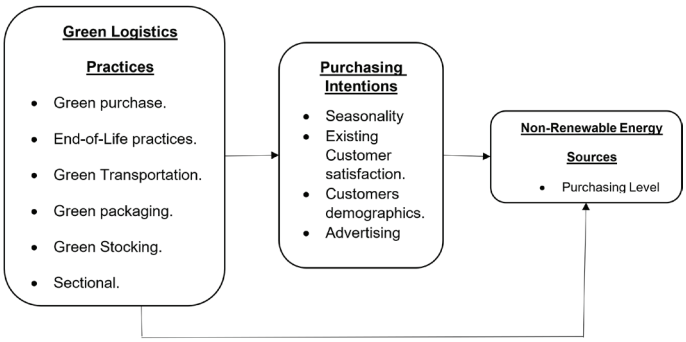


Figure 2: Theoretical framework (by researcher)

## Methodology

This study uses a qualitative approach, conducting semi-structured interviews to explore the role of green logistics practices in reducing nonrenewable energy consumption. It starts with a Systematic Literature Review (SLR) to identify key themes and gaps related to green logistics practices, including green purchasing and reverse logistics, and the moderating role of purchasing intentions. The interviews, conducted with ten logistics experts in Egypt, aim to assess the current state of green logistics and validate the theoretical framework, offering practical insights and a comprehensive understanding of the impact of green logistics on sustainability. The integration of the SLR and interview findings ensures a robust and comprehensive understanding of the studied variables, allowing the research to explore the impact of green logistics practices on reducing reliance on nonrenewable energy sources while fostering sustainability. The researcher presented a set of questions related to the study variables. These questions were included in the semi-structured interviews conducted with the interviewees; these questions are:

What are the current strengths of Egypt's Energy management system, particularly related to the applicability of green logistics practices?

What is the primary motivation for applying green logistics practices in your organization?

Does your organization have any standards for green logistics practices?

Can you provide any examples of your organization's advertising techniques to enhance the green logistics purchase processes?

How would you describe the most recent practice applied by your firm regarding green purchases?

How does the current infrastructure for green logistics practices' applicability support the purchasing level of nonrenewable energy products?

What are the biggest weaknesses you see in Egypt's current approach to managing green logistics practices?

What are the potential environmental or economic threats associated with the applicability of green logistics practices in Egypt?

What were the expectations held by your organization for the impact of applying Green Logistics Practices on the purchasing intention of customers?

What influences the purchase intention of customers to buy renewable energy products?

What indicators, if any, does your company currently use to measure purchasing levels in the renewable energy product sector?

How would you describe the most recent practice applied by your firm regarding green purchases?

What are the main factors affecting the purchasing level of renewable energy products?

What do you think your firm's next step in enhancing the purchasing intentions of customers should be?

The researcher conducted ten interviews with experts working in the supply chain logistics field in Egypt. Face-to-face interviews were conducted with 10 experts working in the following job positions. Table 1 shows the position of each interviewee and the duration of each interview.

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Table 4: Interview Description

| Interview | Job title | Duration |
|---|---|---|
| Interview (1) | Head of the Energy Unit in the field of Sustainable Energy | 18 Minutes |
| Interview (2) | General Manager of Energy Transition, Sustainability, and Renewable Energy (E-GAS) and Assistant GM for Energy & Sustainability in Operations at Paranoiac Petroleum | 20 Minutes |
| Interview (3) | Supply Chain Professional: Business Developer Manager (DSV-Global Transport and Logistics), Customer Relationship Manager (Agility), Project Manager (Agility Kenya), and Assistant Manager (Contract Logistics Sales, Agility) | 15 Minutes |
| Interview (4) | Professor at Arab Academy for Science, Technology and Maritime Transport (Electrical Engineering Department); Certified Energy Manager (CEM); Approved Renewable Energy System Consultant (Egyptian Syndicate); Registered UN Energy Consultant; Official ICT Energy Consultant for GTEX/MENATEX Program | 22 Minutes |
| Interview (5) | Expert at the Environmental Affairs Agency (headed by the Council of Ministers and the Arab Academy for Science, Technology, and Maritime Transport | 23 Minutes |
| Interview (6) | Former Minister of Petroleum and Mineral Resources | 27 Minutes |
| Interview (7) | Head of Department R&D for Training at EPROM Petroleum Company | 16 Minutes |
| Interview (8) | Head of Technical Monitoring Section at Gas Regulatory AuthorityGASREG) | 21 Minutes |
| Interview (9) | Petroleum and Environmental Consultant at EPROM & PETROBEL | 23 Minutes |
| Interview (10) | Pipeline Operations Manager at Sumed | 29 Minutes |

## Research Findings and Discussion

This empirical study is conducted in two phases. The first phase investigates the current state of green logistics and renewable energy use in Egypt, while the second phase develops a conceptual.

A framework linking green logistics practices to nonrenewable energy purchasing intentions. The study includes interviews with industry experts, which provide insights into the adoption of green logistics and its impact on consumer behavior. Thematic analysis using NVivo software helps identify key trends and factors affecting the adoption of green logistics and its influence on energy consumption patterns.

## Assessing the Current Situation

The first aim of the interviews is to assess the current state of green logistics and renewable energy usage in Egypt. The questions asked during the interviews focused on understanding the situation both at a national level and within individual companies. The responses provided by the participants highlighted key details and insights regarding the current practices and challenges in Egypt related to green logistics and renewable energy.

For the first question “What are the current strengths of Egypt’s energy management system, particularly related to green logistics practices applicability?”, interview one has mentioned many strength points that support the adoption of green logistics in Egypt, as the respondents mentioned that “An assessment of Egypt’s energy management system and its strengths related to green logistics practice are available in many ways such as, Energy Efficiency Standards”, and “Egypt has implemented energy efficiency standards for buildings and industries, which have led to a reduction in energy consumption and greenhouse gas emissions”. In interview four, the respondents indicated that “The energy management system has been reinforced by the government’s dedication to renewable energy initiatives, which are backed by foreign investments and collaborations.”

Question seven, “What are the biggest weaknesses you see in Egypt’s current approach to managing green logistics practices?” refers to the weaknesses related to the green logistics practices. It was mentioned in interview six that “As a Former Minister of Petroleum and Mineral Resources, I see that Egypt’s current approach to managing green logistics practices lacks clear regulations and incentives for companies to prioritize sustainability. Additionally, there is a need for greater investment in renewable energy infrastructure to support the transition towards eco-friendlier transportation options.” In addition to that, interviewee seven referred

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to the following weaknesses: “Unfortunately, the concept of sectional reverse logistics is not fully developed in the Egyptian firms regarding green logistics, leading to inefficiencies in waste management and resource utilization”.

When asking about the potential threats facing the green logistics practices as mentioned in question eight “What are the potential environmental or economic threats associated green logistics practices applicability in Egypt?”, interviewee six has illustrated different potential threats mentioned in the following quotes “Potential environmental threats associated with green logistics practices in Egypt include increased costs for companies implementing sustainable measures, as well as the challenge of changing established transportation and supply chain.

Moreover, interview nine has indicated that “Potential environmental and economic threats in Egypt related to green logistics include high initial costs, outdated infrastructure, inconsistent regulations, and possible economic disruption from shifting practices”.

After discussing the questions related to the current Egyptian situation, it is noticed that the answers to question six, “How does the current infrastructure for green logistics practices applicability support the purchasing level of nonrenewable energy products?” include both a description of the current situation in Egypt and a description of the companies’ situation. For example, interview two has referred to the Egyptian situation in the following quotations: “In conclusion, Egypt’s infrastructure for green logistics practices is developing, and there is still room for improvement to support the purchasing level of nonrenewable energy products. By leveraging public-private partnerships, innovative technologies, and policy incentives, Egypt can accelerate the transition to a more sustainable energy landscape.” Interview three mentioned the situation of his company, mentioning that “We engage with local governments and regulatory bodies to advocate for policies that promote the adoption of renewable energy sources in the logistics industry.”

Finally, the questions that target getting a clear understanding of the organization’s situation are mentioned. For the third question, “Does your organization have any standards for green logistics practices?”, three interviewees indicated that “We also have specific standards for measuring and reporting our carbon footprint, which enables us to track our progress and make informed decisions.” In addition, interview seven has confirmed this point: “In EPROM Petroleum, we are obliged to follow strict guidelines for reducing our carbon footprint and implementing sustainable transportation methods. This includes using electric vehicles, optimizing delivery routes, and minimizing packaging waste. We mainly focus on reducing emissions and promoting environmental sustainability in all aspects of our operations.”

Question five, which asks about “How would you describe the most recent practice applied by your firm regarding green purchases?”, interview one mentioned that “Green logistics practices such as the use of green fuels, such as biofuels or compressed natural gas (CNG).” Interview ten has indicated that “Our most recent practice involved implementing a comprehensive recycling program at all our facilities, ensuring that waste is properly sorted and disposed of in an environmentally friendly manner. This initiative has significantly reduced our carbon footprint and reinforced our commitment to sustainability in all aspects of our operations.”

According to question twelve “How would you describe the most recent practice applied by your firm regarding green purchases?”, interview five has mentioned the latest practices through the following two quotes; “Our latest initiative involves forming a green procurement network in collaboration with other organizations. This network aims to streamline the purchasing process for green products and services, making it easier for companies to adopt sustainable practices. “We’ve also introduced training programs for our procurement team to enhance their understanding of green products.”

Finally, question fourteen “What do you think your firm’s next step in enhancing the purchasing intentions of customers should be?” interview eight has referred to two main practices done by his company to enhance the customers’ awareness and purchase intention “Implementing a loyalty program to reward repeat customers and encourage brand loyalty could also be an effective strategy to enhance purchasing intentions.” In addition, interview nine assured that “EPROM targets can include measures such as flaring reduction, pollution prevention, or reducing our impact on biodiversity. Since impacts to the environment vary from site to site according to the nature of each operation, we consider the different environmental sensitivities in determining which issues require the greatest focus for impact reduction in each site.”

Egypt is focusing on adopting green logistics and utilizing renewable energy sources. However, challenges remain, particularly in infrastructure, hindering the complete implementation of green logistics. Different organizations have varying concerns regarding the adoption of green logistics. A SWOT analysis was conducted based on semi-structured interviews and a systematic literature review to evaluate the strengths, weaknesses, opportunities, and threats of green logistics and renewable energy use.

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Table 5 presents the SWOT analysis based on these findings.

Table 5: SWOT Analysis

| Strength | Weakness |
|---|---|
| • Egypt has abundant renewable resources like solar and wind energy.<br>• Strong government support for renewable energy through policies and incentives.<br>• Strategic location, serving as a bridge between Africa and the Middle East.<br>• Growing energy demand due to population growth and industrial expansion.<br>• Established energy infrastructure that can integrate renewable energy projects.<br>• Alignment with Egypt Vision 2025, providing clear direction and regulatory support. | • High initial costs for renewable energy projects.<br>• Complex regulatory frameworks and bureaucratic delays.<br>• Limited grid capacity and stability for large-scale renewable integration.<br>• Lack of local expertise in renewable energy technology and project management.<br>• Financial constraints and limited access to investment. |
| **Opportunities** | **Threats** |
| • Egypt's renewable energy potential is potentially attractive for international investment.<br>• Technological advancements that could reduce costs and improve efficiency.<br>• Egypt has the potential to become a regional renewable energy hub that exports electricity.<br>• Job creation and economic diversification through the renewable energy sector. | • Economic instability and currency devaluation are affecting project viability.<br>• Political and social unrest.<br>• Competition from fossil fuels, with subsidies and entrenched interests undermining renewables.<br>• Climate change impacts that could affect renewable energy infrastructure.<br>• Regulatory uncertainty. |

The SWOT analysis highlights Egypt's strengths in green logistics, such as strong public-private partnerships and government support. However, challenges include unclear regulations, lack of incentives, poor renewable energy infrastructure, and weak reverse logistics. Opportunities lie in

Expanding renewable energy and collaborating with sustainable suppliers. Threats include high costs, outdated infrastructure, and low consumer awareness.

## Verifying Theoretical Framework

To have a comprehensive grasp of the subjects covered by the study population, the researcher needs to adhere to a set of procedures in the theme analysis process. There are six stages in these steps, which are as follows:

Familiarization with the Data: The first step is transcribing and thoroughly reviewing the collected data.

Producing the Initial Codes: The second phase involves coding and categorizing data into themes, with all responses being extracted and arranged.

Looking for Themes: The third phase focuses on identifying recurring ideas or concepts in the data, often visualized through a word cloud or thematic map, as shown in Figure 1.


Figure 3: Word Cloud

**Phase 4:** Reviewing Themes: Researchers synthesize individual codes and categories into broader themes. The themes are classified by grouping related codes and isolating unique ones. Four key themes emerged from the interview responses:

Theme of Green Logistics Practices

Theme of Purchasing Intentions

Theme of Purchasing Level of Nonrenewable Energy Sources

Theme of Logistics Solutions

Phase 5: Naming and Defining: The primary themes

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are named and defined, with their corresponding codes and frequency of occurrence summarized in Table 2.

Table 6: Summary Table of Themes and Codes

| Theme | Code | Reference | Total |
|---|---|---|---|
| **Theme of Green Logistics Practices** | Green Purchase | 16 | 59 |
| | End-of-Life Practices | 5 | |
| | Green Transportation | 12 | |
| | Green Packaging | 10 | |
| | Green Stocking | 5 | |
| | Sectional Reverse Logistics | 4 | |
| | Reverse Logistics | 7 | |
| **Theme of Purchasing Intentions** | Purchasing Intention Drivers | 15 | 38 |
| | Consumer Awareness and Education | 10 | |
| | Advertising Influence | 13 | |
| **Theme of Purchasing Level of Nonrenewable Energy Sources** | Cost Considerations | 10 | 21 |
| | Environmental Awareness | 11 | |
| **Theme of Logistics Solutions** | CO2 reporting | 4 | 26 |
| | Supply chain optimization | 7 | |
| | Sustainable warehousing | 6 | |
| | Sustainable fuels | 9 | |

Phase 6: Report writing: In this phase, the researcher compiles the results of the data analysis and prepares the final report. The report is created after thoroughly reviewing the selected themes, and this step is outlined in the following sub-sections.Theme of Green Logistics Practices

The analysis of interviews revealed four themes, with "Green Logistics Practices" as the first, encompassing codes like Green Purchase, End-of-Life Practices, Green Transportation, Green Packaging, Green Stocking, Sectional Reverse Logistics, and Reverse Logistics. These codes illustrate how organizations integrate eco-friendly methods, as shown in Figure 2.


Figure 4: Theme of Green Logistics Practices

Green Purchase, a key component of Green Logistics Practices, aims to reduce nonrenewable energy use by leveraging purchasing intentions, as highlighted in the interviews. The following details were mentioned in regard to this evidence in the first, second, eighth, and tenth interviews as follows: "The Egyptian Government's Ministry of International Cooperation has launched a social media campaign to promote sustainable logistics practices in Egypt", "Sustainable Procurement Framework: Where establishing a comprehensive sustainable procurement framework that considers environmental, social, and governance (ESG) factors in countries purchasing decisions", "Our most recent practice is "Network Tariff", Network Tariff is the payment made by the network user to the Network Operator in exchange for the right to use" and

"Our most recent practice involved implementing a comprehensive recycling program at all of our facilities, ensuring that waste is properly sorted and disposed of in an environmentally friendly manner".

End-of-Life Practices are vital to Green Logistics Practices, aiming to reduce nonrenewable energy use in Egypt, with purchasing intention as a mediating factor, as highlighted in the interviews. The following examples of this proof were presented in the first, sixth, eighth and tenth interviews: "Through adoption of electric vehicles can lead to challenges in managing the disposal and recycling of batteries, which contain hazardous materials", "We are also keen on providing adequate End-of-Life practices to our customers", "Some practices should be involved in the industrial context including the end-of-life practices, which may help in reducing the pollution and manage the consumption of

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Egyptians" and "Moreover, we encourage our partners to use green packaging and the end-of-life policy".

Green Transportation, highlighted in interviews, is a key aspect of Green Logistics Practices, impacting nonrenewable energy use and influenced by purchasing intention in supply chain logistics. This evidence was referenced in the first, second, and third interviews as follows: "The goal is to have EVs constitute 15% of the total fleet by 2025, significantly reducing carbon emissions", "The country is developing green ports, such as the new Ain Sokhna Port, which will enable the efficient handling of cargo while reducing environmental impact", "The use of electric and hybrid vehicles in logistics operations is becoming increasingly popular in Egypt, reducing emissions and operating costs" and "We also work with suppliers who offer sustainable energy options, such as biofuels or electric vehicles, to power their operations".

Green Packaging, identified in interviews, plays a crucial role in Supply Chain Logistics, influencing nonrenewable energy use through purchasing intention in the Egyptian context. This evidence was referenced in the sixth, seventh, and ninth interviews, as follows: "We managed to implement several green logistics practices in our organization, such as optimizing transportation routes and using eco-friendly packaging materials", "This includes using electric vehicles, optimizing delivery routes, and minimizing packaging waste" and "Our packaging standards aim to reduce our environmental impact. We use recyclable and biodegradable materials and design packaging to use less material while still protecting the product during shipping".

Green Stocking, highlighted in interviews, is vital to Green Logistics Practices, aiming to reduce nonrenewable energy use with purchasing intention as a mediating factor in Egypt. The following details were mentioned in regard to this evidence in the fourth, fifth, seventh, and tenth interviews as follows: "Through the years from 2020 to 2024 I witness a lack of green stocks in Egypt in general, which is not very promising", "Green stocks are also becoming increasingly popular among investors who prioritize environmental responsibility and sustainability practices", "I remember the popularity of our green stocks due to the awareness of the importance of sustainability in our industry" and "We are currently working on improving our green stocks implementation and management".

Sectional Reverse Logistics, identified in interviews, is a key aspect of Green Logistics Practices, influencing nonrenewable energy use through purchasing intention in Egypt. This evidence was referenced in the fifth, sixth, seventh and ninth interviews as follows: "The sections and departments in our organizations are keen on developing innovative green logistics practices", "Thus, every section should have a variety of reverse logistics to help in maintaining an adequate portion of innovation in the green logistics practices", "Unfortunately, the concept of sectional reverse logistics is not fully developed in the Egyptian firms regarding green logistics, leading to inefficiencies in waste management and resource utilization" and "We've got a clear process for handling returns and recycling. This means efficiently managing product returns and focusing on refurbishing and recycling materials to cut down on waste".

Reverse Logistics is a crucial component of Green Logistics Practices, influencing nonrenewable energy use through purchasing intention in Egypt, as highlighted in the interviews. This evidence was referenced in the first, second, third and seventh interviews as follows: "The integration of advanced technologies plays a critical role in optimizing logistics operations and reducing environmental impact", "The government has implemented waste management programs, including recycling initiatives, to reduce waste disposal costs and minimize environmental impacts", "This involves designing products with recyclable materials and implementing take- back programs to collect used products for recycling" and "Showcasing testimonials from satisfied customers who have benefitted from our reverse green logistics solutions could also be a powerful advertising technique to highlight the positive impact of our services"

## Theme of Purchasing Intentions

The interviews revealed a key theme, "Purchasing Intentions," with codes like Purchasing Intention Drivers, Consumer Awareness, and Advertising Influence. These codes explore factors shaping consumer decisions and their impact on purchasing behavior, providing a visual representation in the analysis, as shown in Figure 3.


Figure 5: Theme of Purchasing Intentions

Purchasing Intention Drivers are crucial in shaping the purchasing level of nonrenewable energy sources, aligning with the study's focus on Green Logistics Practices and mediation through purchasing intention. This evidence was referenced in the second, third, and fourth interviews as follows: "The

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growing demand for sustainable solutions is driving a trend towards renewable energy adoption, with many customers seeking to stay ahead of the curve", "Our organization expected that applying Green Logistics Practices would lead to increased customer loyalty and retention. We believed that by adopting eco-friendly practices, we would demonstrate. Our commitment to sustainability and social responsibility, which would positively influence customer purchasing decisions," and "In our organization, we expect that applying green logistics practices will positively impact purchasing intentions. Customers increasingly value sustainability, and demonstrating a commitment to green practices can enhance brand loyalty and attract environmentally conscious consumers".

Consumer Awareness and Education are key factors influencing Purchasing Intentions, impacting the purchasing level of nonrenewable energy sources through the mediation of purchasing intention, as revealed in the interviews. The seventh, eighth, ninth, and tenth interviews clarified this evidence as follows: "Firstly, the awareness of customers, and then comes the offers and discounts offered by the company, I can also say that advertising programs are totally related to the purchasing level", "We are currently working on a project regarding raising the awareness of Egyptians of how to make informed purchasing decisions through educational workshops and online resources", "Through targeted advertising, we promote the benefits of green logistics, which educates consumers about the environmental impacts of their purchases. This increased awareness helps drive demand for more sustainable practices, even in the context of nonrenewable energy products, and "We were pleasantly surprised to see a gradual increase in purchasing intention as customers became more educated on the benefits of green logistics".

Advertising influence plays a significant role in shaping purchasing intentions, impacting the purchasing level of nonrenewable energy sources, and aligning with the research's focus on green logistics practices. This evidence was referred to from the first interview to the fourth interview as follows: "The Egyptian Government's Ministry of International Cooperation has launched a social media campaign to promote sustainable logistics practices in Egypt. They use hashtags like #Green Logistics EG to raise awareness about the importance of environmentally friendly logistics and encourage companies to adopt green practices", "We advertise this program through targeted ads on our website, social media, and email campaigns", "Promote eco-friendly packaging options, such as biodegradable or recyclable materials, to reduce waste and minimize environmental impact. We showcase these options on our website and social media channels. To promote green logistics practices, we use various advertising techniques to raise awareness among our customers and stakeholders about the benefits of sustainable logistics. We utilize various advertising techniques, including digital marketing campaigns that highlight our commitment to green logistics and sustainability.

## Theme of Purchasing Level of Nonrenewable Energy Sources

The third theme, "Purchasing Level of Nonrenewable Energy Sources," was identified with codes Cost Considerations and Environmental Awareness. These themes illustrate key factors.

Influencing the purchasing level of nonrenewable energy sources, as visualized in Figure 4.


Figure 6: Theme of Purchasing Level of Nonrenewable Energy Sources

Cost Considerations are a key factor influencing the purchasing level of nonrenewable energy sources, aligning with the study's focus on Green Logistics Practices and mediation through purchasing intention. The following details were mentioned regarding this evidence in the first, fifth, and sixth interviews as follows: "The upfront cost of renewable energy vehicles (e.g., electric trucks, hydrogen-powered freight vehicles) is often higher than that of conventional fossil fuel vehicles", "Economically, the initial costs of adopting green logistics practices can be a hurdle, particularly for small and medium-sized enterprises (SMEs)" and "The main factors affecting the purchasing level of renewable energy products include cost competitiveness, availability of incentives or subsidies, consumer awareness and education, and government policies supporting renewable energy development".

Environmental awareness is crucial in reducing the use of nonrenewable energy in Egypt's logistics sector. This aligns with the study's goal of examining how environmental awareness impacts sustainability, specifically through the mediation of purchasing intentions. The findings underscore the significance of incorporating environmental consciousness into logistics operations to achieve broader sustainability objectives as follows: "There's a growing consumer preference for

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sustainable and eco-friendly products", "Implementing green logistics practices can help mitigate these threats and create a more sustainable future for the country", "Our main threat is the co2 emissions and their impact on climate change. Additionally, the reliance on fossil fuels for transportation in Egypt poses a risk to air quality and public health" and "Unfortunately, we did not expect much after applying the 14001 Iso requirements, as we were unsure of how much awareness our customers had about environmental sustainability practice".

### Theme of Logistics Solutions

The fourth theme, "Logistics Solutions," focuses on strategies for enhancing sustainability and efficiency in logistics operations. This theme includes codes such as co2 reporting, supply chain optimization, sustainable warehousing, and sustainable fuels, contributing to environmentally sustainable practices. This detailed categorization highlights the importance of these solutions in reducing environmental impact and optimizing supply chain performance, as shown in figure 5.


Figure 7: Theme of Logistics Solutions

CO2 Reporting is a crucial factor in enhancing Logistics Solutions, aiding in the reduction of nonrenewable energy use through improved sustainability practices. This evidence was referenced in third, fourth, sixth, and seventh interviews as follows: "We track our energy consumption and carbon footprint through our Environmental Management System (EMS) and report it annually to our stakeholders", "Recently, our firm implemented an inclusive review of our supply chain to identify opportunities for green purchases and CO2 reduction practices. We prioritized sourcing from suppliers with strong environmental credentials and encouraged the use of recyclable and biodegradable materials", "Our most recent practice involves implementing a carbon offset program for all transportation, further reducing our environmental impact" and "I believe that Co2 reporting represents an essential step in enhancing the purchasing intentions of customers, as it provides transparency and accountability in environmental impact".

Supply chain optimization is a vital component of logistics solutions, influencing the purchasing level of nonrenewable energy sources by enhancing sustainability and efficiency, which is aligned with the study's focus on green logistics practices. This evidence was referenced by the first, third, sixth, and seventh interviews as follows: "Advanced logistics planning tools enable optimized routing of transportation vehicles, reducing fuel consumption and emissions", "A set of solutions ranging from CO2 reporting, supply chain optimization, sustainable warehousing to sustainable fuels and carbon offsetting", "We also need to optimize the supply chains in Egypt to offer a suitable environment for the renewable energy adaptation" and "In EPROM Petroleum, we are obliged to follow strict guidelines for reducing our carbon footprint and implementing sustainable transportation methods. This includes using electric vehicles, optimizing delivery routes, and minimizing packaging waste".

Sustainable Warehousing plays a significant role in Logistics Solutions, contributing to the reduction of nonrenewable energy use and supporting sustainable logistics practices. This evidence was referenced in the third, fourth, fifth, and seventh interviews as follows: "The latest practice involves installing energy-efficient lighting and HVAC systems in our warehouses", "We can also make sure that our warehouses are sustainable, this will enlarge the customer trust in the organization", "We need to enhance our usage of sustainable fuel and sustainable warehouses" and "Additionally, we have been working closely with suppliers who prioritize sustainability in their production processes".

Sustainable Fuels are crucial for reducing nonrenewable energy use in logistics, aligning with the study's focus on Green Logistics Practices and Purchasing Intention mediation in Egypt. This evidence underscores the pivotal role Sustainable Fuels play in driving sustainable logistics.

Solutions and supports the study's overarching goals: "Egypt has launched a green hydrogen initiative to produce hydrogen from renewable energy sources, which can be used as a clean alternative for transportation and power generation. "We provide sustainable fuel options across our air, sea, and road services. Plus, as we only use suppliers who meet sustainability criteria of various accredited frameworks, you can rest assured that you are truly getting closer to de-carbonization", "Biofuels, whether for aviation, road or sea, are more sustainable than diesel due to the lowered $CO_2$ emissions from Biofuels" and "Transitioning to sustainable fuel in Egypt is crucial for long-term sustainability and reducing carbon emissions. Collaborating with stakeholders and investing in research and development for alternative fuel sources can help overcome these challenges".

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## Discussion and Conclusion

The study examines how Green Logistics Practices (GLP) influence nonrenewable energy use in Egypt, with purchasing intention as a mediator. A literature review confirmed that GLP, including eco-friendly transportation, packaging, and reverse logistics, impacts consumer purchasing behavior and reduces nonrenewable energy dependence. Interviews revealed Egypt's efforts to cut energy consumption and emissions, with strong public-private collaboration. The study identified four key themes: GLP, purchasing intentions, nonrenewable energy purchasing levels, and logistics solutions. A mind map was created to illustrate these relationships, offering insights for enhancing green logistics and promoting renewable energy adoption in Egypt's sustainable development. The following mind map is developed from the analysis, which reflects the themes and sub-themes developed from the analysis, as shown in Figure 6.

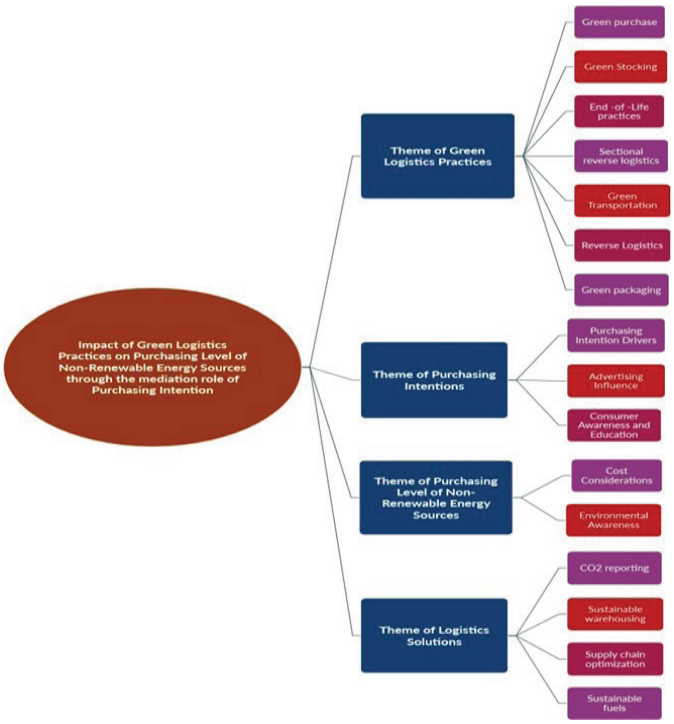


Figure 8: Research Mind Map

After developing the mind map and comparing it to the theoretical framework, the conceptual framework of the study is developed, which is shown in Figure 4-9. The variables and dimensions of the theoretical framework are accepted; in addition to that, dimensions for the purchasing level of nonrenewable energy sources variable are added, which are: cost consideration and environmental awareness. In addition to that, one dimension of green logistics practices is modified from sectional-to-sectional reverse logistics.

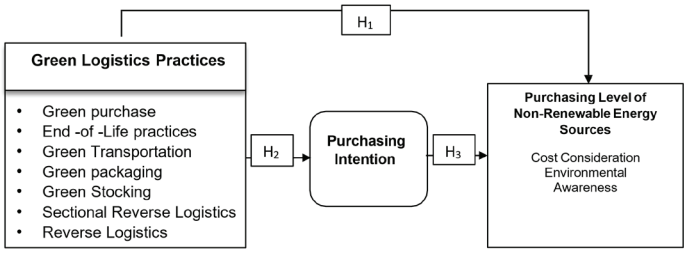


Figure 9: The Conceptual Framework

This study explored how Green Logistics Practices (GLP) influence nonrenewable energy use in Egypt, with purchasing intention as a mediator. It found that Egypt is making strides in green logistics and emissions reduction through public-private collaborations, but faces challenges like weak infrastructure, inconsistent regulations, and low consumer awareness. The study developed a framework showing how GLP and purchasing intentions can reduce reliance on nonrenewable energy, offering insights for policymakers and organizations.

## Recommendations

To promote green logistics and sustainability in Egypt, the following recommendations are proposed:

Policy Development: Create clear regulations and incentives to encourage the adoption of green logistics and renewable energy investment.

Infrastructure Improvement: Upgrade transportation and logistics infrastructure to support sustainable practices like reverse logistics and green warehousing.

Awareness Campaigns: Launch nationwide campaigns to educate consumers on the benefits of green products and renewable energy, influencing purchasing intentions.

Public-Private Partnerships: Strengthen collaborations between the government and private sector to align resources and goals for sustainable logistics.

Support for Businesses: Offer financial and technical assistance to businesses, especially SMEs, transitioning to sustainable operations.

### Implications

This research offers both practical and theoretical implications:
Practical Implications: The study provides actionable insights for practitioners and policymakers in logistics and renewable energy sectors. By adopting green logistics practices, organizations can reduce

environmental impact, build consumer trust, and align with global sustainability trends. It also emphasizes the need to address consumer behavior to effectively implement green initiatives.

Theoretical Implications: The research contributes to the literature by developing a comprehensive conceptual framework that integrates Green Logistics Practices (GLP), purchasing intention, and nonrenewable energy demand. This framework can guide future studies exploring the relationship between sustainability practices and consumer behavior in various contexts.

## Limitations and Suggestions for Future Research

This study has several limitations, including its focus on Egypt, which may limit the generalizability of the findings. The small sample size of expert interviews and reliance on qualitative data also restrict the robustness of the results. Future research could include larger and more diverse samples, integrate quantitative methods, and explore additional variables like government policies or technological advancements. Addressing these limitations would help further advance the understanding of green logistics practices and renewable energy adoption.

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# Interrelations of Logistics Performance and Trade Promotion: A Systematic Review

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## Abstract

***Purpose**: This study conducts a comprehensive review of how the Logistics Performance Index (LPI) is used to measure logistics performance, and explores its relationship with green transportation, logistics eco-innovations, and trade enhancement.*

***Design/Methodology/Approach**: Following PRISMA guidelines, a systematic review was carried out on English-language, peer-reviewed articles published between 2000 and 2025, sourced from Scopus, Web of Science, and ScienceDirect. Two reviewers independently handled screening, data extraction, and appraisal. A total of 21 quantitative studies met the inclusion criteria, with sample sizes ranging from 17 to 622 respondents.*

***Findings:** The review reveals widespread reliance on the LPI for evaluating logistics systems, despite certain limitations. It also finds that green transportation initiatives and logistics eco-innovations play a crucial role in reducing $CO_2$ emissions, lowering pollution, and supporting environmental sustainability. Additionally, improved logistics performance—as measured by LPI—has a positive effect on trade promotion, especially in developing countries.*

***Theoretical Contribution:** This study enriches logistics and supply chain literature by synthesizing evidence that positions the LPI as a pivotal link between logistics efficiency, sustainable practices, and trade growth.*

***Practical Contribution:** The insights gained offer practical guidance for policymakers and logistics professionals, highlighting how LPI-informed strategies can boost trade competitiveness while advancing sustainable logistics.*

***Keywords:** Logistics performance, green transportation, eco-innovations, trade promotion, developing nations.*

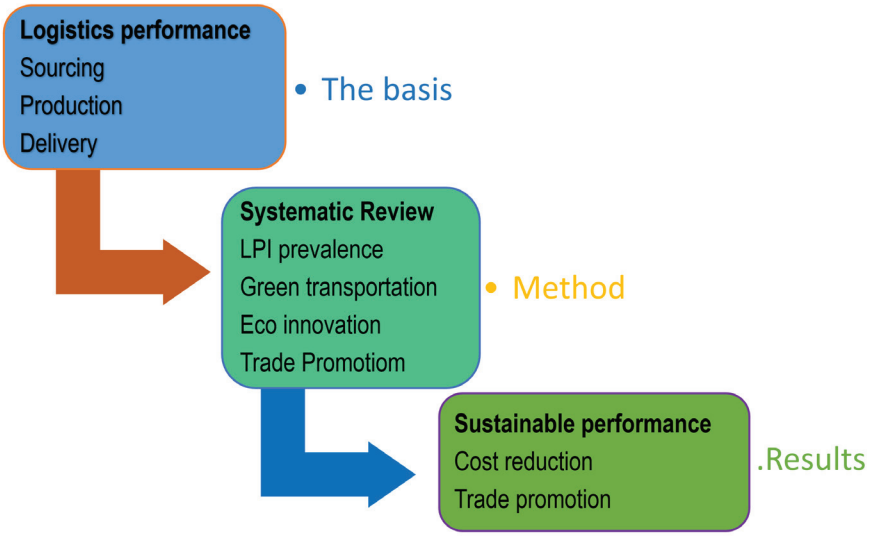


Figure 1: Abstract's graphical illustration

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## Introduction

Logistics is a crucial sector that, apart from enhancing the competitiveness of a firm, also promotes the national economic performance and development of a country (Li et al., 2023; Rashidi & Cullinane, 2019). Effective logistics promote economic growth through the production and distribution of goods at reduced costs and enhance customer demand by embracing reliable mechanisms (Domagała et al., 2022; Nikseresht et al., 2024). It also promotes trade through producers' ability to access far-off markets, ability to reduce inventories, gaining foreign direct investment, sustainable competitiveness achievement, and job creation opportunities in the logistics sector (Klymenko & Halse, 2022; Waiyawuththanapoom et al., 2021). Though the logistics industry has contributed immensely to global economic growth, it has brought about significant environmental challenges with the inclusion of noise pollution, emissions of environmental pollutants, traffic congestion, mass landfill through garbage and waste generated in the production process, and daily life as a result of transportation methods. There is a growing worldwide concern regarding our planet's ecological protection due to major pollution incidents emanating from logistics activities.

Innovation is one of the major ways through which environmental protection goals can be achieved (Borrás & Edquist, 2013). Technological innovation provides novel inspirations toward low carbon dioxide emissions and green environment protection (Yi et al., 2020). Other scholars have concurred with this crucial role of technological innovations. For instance, Pan et al. (2019) established a significant relationship between technological innovation and energy efficiency improvement. Similarly, Ibrahiem (2020) indicated that technological innovation improves the quality of the environment to a large extent. Furthermore, Lahouel et al. (2021) demonstrated that science and technology innovation play a crucial role in improving the whole factor green productivity, while information and communication technology facilitates green economy development.

To measure a country's logistics performance, the World Bank, in conjunction with Finland's Turku Institute of Economics, devised the national Logistics Performance Index (LPI) in 2007. This became the initial step toward comprehensively evaluating the development level of logistics performance in different countries. LPI is a derivative of a standardized questionnaire that takes online surveys and then makes use of principal component analysis to compose the data into a single index. The values range between 1 and 5, with one as an indicator of low logistics performance and 5 indicating high performance. The results are released every two years, with the first release in 2007 (Arvis et al., 2018). The six components of customs, infrastructure, services, timeliness, tracking and tracing, and international shipments inform the LPI.

LPI, as an interactive benchmarking tool, identifies eminent opportunities and challenges associated with logistics performance. Arvis et al. (2018), in pursuit of exploring the state of logistics performance in different nations, established that while low-income nations concentrated on logistics infrastructure and facilitation of transport, countries in the middle-income earners' band focused on efforts toward improvement of logistics skills, services, and trade regulations. On the other hand, high-income nations were more focused on the state of green logistics and information systems. Green logistics impacts a country's trade performance through cost reduction, timeliness, consistency, and customer service, all of which influence the overall global export competitiveness (Yingfei et al., 2022). Therefore, the LPI is not without limitations, and while some scholars appreciated the use of LPI as a unifying factor in measuring the effectiveness of the logistics sector at the international level, they argued that it was not generally suitable to measure domestic or in-country performance (Nayak et al., 2024; Nguyen & Le, 2024). Against this backdrop, to fill the mentioned gaps, this study sought to conduct a systematic review on the role of logistics performance in trade promotion while guided by the following specific objectives:

1. To determine the propensity to use the logistic performance index as a measure of logistics performance
2. To establish the implications of green logistics on trade promotion
3. To explore logistics eco-innovation adoption and its association with trade promotion.

## Literature Review

Logistics is one of the key areas that supports the direct establishment of customer relationships and enhances organizations' long-lasting competitive advantage (Ali et al., 2022). Erturgut (2016) regarded logistics performance as the high-quality implementation of logistics activities when delivering products from the source to the end consumer with prompt consideration of logistics principles as well as customer satisfaction. How efficiently logistics activities are adopted significantly influences an organization's capability to satisfy customer requirements at the minimal cost possible (Marchesini & Alcântara, 2016). Fahimnia et al. (2011) noted that it is imperative to monitor logistics performance across the entire supply chain, right from the raw materials' supply up to the end user or the

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individual consumer. The impetus to reduce costs while increasing logistics performance is directly associated with an improvement in both local and international trade (Carlucci et al., 2018).

Arshed et al. (2022) noted that the association between logistics and trade promotion is one of the most researched topical issues in the recent past. This has led to a skewed interest in logistics performance measurement in different organizations. As argued by Waśniewski (2021), adequacy in the performance measurement system is paramount to all logistics organizations. The establishment and construction of logistical performance must therefore directly communicate with the proposed objective achievement of a firm. Different approaches have been used to measure logistics performance. For instance, Mentzer and Konrad (1991) used the logistics activities' concept of transportation, inventory management, warehousing, and order processing, among other logistics management subcategories, to determine logistics performance. Logistics effectiveness, superiority, or differentiation and efficiency concepts have also been used in numerous studies as measures of logistics performance (Bobbitt, 2004; Fugate et al., 2010). The introduction of LPI in 2007 became the initial step toward comprehensively evaluating the logistics performance of different countries. Although without limitations, LPI has been used as a yardstick in measuring logistics performance, and different scholarly works have evaluated its association with various factors such as economic growth, green transportation, innovation, and trade, among others.

The green supply chain has increasingly become a hot topic in the management science field, with green logistics as its subcategory. According to Wu and Dunn (1995), green logistics is an overall environmentally friendly logistics system comprising green transportation, green warehousing, reverse logistics, and waste recycling. The main drive toward green logistics adoption is the achievement of a sustainable balance in the relationship between economic, environmental, and social gains (Dekker et al., 2012). The three categories are anchored on the Bottom Line sustainability framework (TBL), which challenges industries to include the security of people and planet protection in their pursuit of economic achievements (Griggs et al., 2013). Several studies have linked TBL with green transportation and firm performance. For example, Lai and Wong (2012) established a significant positive relationship between green logistics management and environmental quality improvement and business performance at the manufacturing level. Regulatory pressures also promoted green logistics and had a positive effect on environmental profitability. D'Aleo and Sergi (2017) also emphasized the competitive edge enjoyed by companies that embrace effective green logistics. These include an increment in the market value of products and cash flow optimization with the inclusion of current and other expenses reduction.

A firm's green logistics services, coupled with efficient procedures, enhance its competitive advantage and increase its performance (Campos & Hardwick, 2006). According to Wong and Tang (2018), in the green logistics realm, efficient supply chain management has a significant positive relationship with a firm's performance since a green supply chain results in enhanced organizational performance, which in turn promotes profitability and market share. This improves the environmental sustainability and financial performance of a firm.

In as much as the logistics sector is considered the global economy's backbone through its crucial role of connecting suppliers with consumers worldwide, the sector is marred by side effects that, if unchecked, would be detrimental to the present and future generations, environmentally speaking. Logistics activities have resulted in elevated fossil fuel combustion and direct release of greenhouse gases (GHG) into the atmosphere, which has a damaging effect on the health and environment in the long run (Magazzino & Schneider, 2020). In 2014, for example, it was noted that the logistics sector was named a major contributor to environmental degradation, accounting for 22% of carbon dioxide ($CO_2$) emissions worldwide. OECD (2017) emphasized the need to embrace green supply chain failure, to which transport emissions of $CO_2$ are projected to rise by 60% by 2050, while global freight alone will take a lion's share of 160%. Therefore, how do firms strike a balance between conducting logistics activities and taking care of the environment? Innovation has been singled out as one of the surest ways of safeguarding the environment (Borrás & Edquist, 2013).

Innovation can generally be termed as "the implementation of a new or significantly improved product (goods/service) or process, a new marketing method, or a new organizational measure in practice, in the work organization or in external relations" (Manual, 2005). Consequently, eco-innovation entails the production, assimilation, and adoption of novel products, services, and processes, which results in the reduction of environmental risks such as pollution and degradation (Kemp & Pearson, 2007). Therefore, in relation to the sustainability of logistics activities, the role of eco-innovation in reducing climate change and curbing environmental pollution cannot be ignored (Greenland et al., 2023). Although there is evidence of significant commitment toward greening through innovation adoption in developing nations, the process is, however, faced by unlimited challenges (Nguyen & Dekhili, 2019; Van Loi et al., 2020). The challenges

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arise from factors such as striking a balance between business growth and the ability to reduce the negative impacts associated with logistics, distribution, and manufacturing operations, in addition to the pollution concerns created by the mushrooming industrialization and urbanization (Li & Qamruzzaman, 2023; Van Loi et al., 2020). The benefits of innovation in the logistics sector outweigh the challenges, with various scholars establishing a significant positive relationship between innovation and sustainable development, corporate performance, competitive advantage, and business growth, among others (Ayinaddis, 2023; Le et al., 2022; Tseng et al., 2022). Different theories that guide firms in the adoption, implementation, and evaluation of innovative technologies have been established. This review will be grounded on the diffusion of innovation theory (DOI), which seeks to establish how firms adopt eco-innovation by considering the following perspectives: innovation's advantages, ease of use, compatibility, trialability, and observability (Rogers, 2003). Extant research has established a few studies examining eco-innovation adoption in developing countries, particularly linking LPI and DOI, hence this review.

## Methodology

To gather, analyze, and synthesize related studies in the field of logistics performance and trade promotion, this paper adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). Page et al. (2021) noted that the use of the PRISMA approach guarantees a comprehensive and unbiased analysis of the reviewed literature. Three databases of Scopus, Web of Science, and Science Direct were searched. The key words included in the search were 'logistics performance', 'logistics efficiency', 'logistics capacity', 'trade promotion', 'business promotion', 'trade support' and 'developing countries." The search strategy adopted Boolean operators of 'AND, OR" in combining the key terms as follows: (*logistics performance OR logistics efficiency OR logistics capacity) AND (trade promotion OR business promotion OR trade support) AND (developing countries OR emerging nations).* This ensured a comprehensive exploration of the related literature. Open-access peer-reviewed journal papers published between 2000 and 2025 were considered for review. The review considered English-only papers within the scope of developing nations that used quantitative data analysis techniques. According to Halog and Anieke (2021), although research in environmental sustainability has gained impetus in the recent past, it is generally a new concept, and slow growth has been evidenced in developing nations apart from China, hence the choice of developing countries and the short time range. The systematic identification and screening process yielded 21 papers that were considered eligible for analysis. The search flow diagram is shown in Fig. 2.

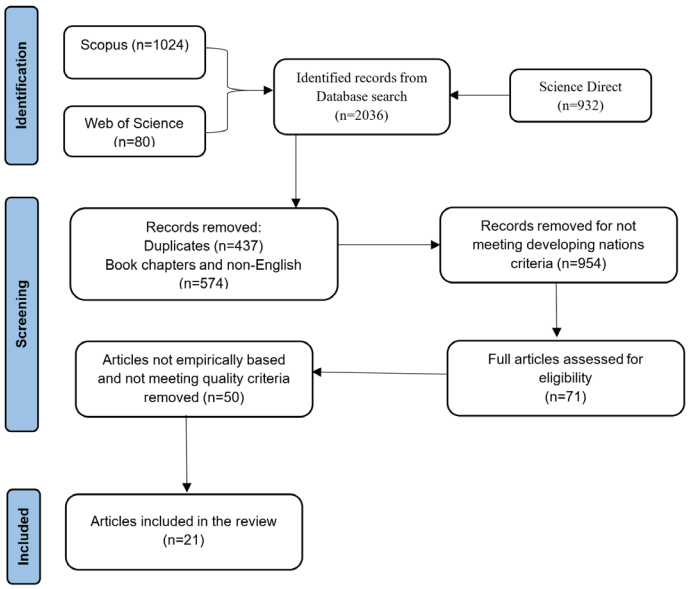


Figure 2: PRISMA flow diagram

## Results

The review narrowed down to 21 peer-reviewed papers that covered cross-cutting topical issues related to logistics performance, green logistics, logistics eco-innovation, and trade promotion. The study area was developing nations as categorized by the World Economic Situation Report (WBG, 2022). Out of the 21 reviewed papers, seven were specifically from China, five from Asian countries 5, Thailand 1, three from Africa 3, three from emerging nations 2, Bangladesh 1, Vietnam 1, and 1 from India. The results section is divided into three categories with seven papers in each category. Category one dealt with papers covering the propensity to use LPI as a measure of logistics performance (Table 1), category two looked at the association between green transportation and trade promotion (Table 2), while the last category dealt with reviewing the interrelations between logistics eco-innovation and trade promotion (Table 3). The papers used quantitative methods of data analysis with a sample size ranging from 17 to 622 respondents. The data collection methods used comprise online surveys, interviews, focus groups, and secondary data from different accredited sources. The wide range of data collection methods, varying sample sizes, and wide geographical scope enriched the understanding of topical issues in relation to logistics performance and trade promotion in developing nations.

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## Propensity to Use the Logistic Performance Index As A Measure of Logistics Performance

Most of the reviewed journal articles jointly underscored the widespread propensity to use LPI as a measure of logistics performance in different countries. They illuminated the six subcategories of LPI of customs, infrastructure, ease of shipment, logistics services, tracking and tracing, and timeliness, whereby in some studies all six subcategories were included, while others included some of them, and the majority used the aggregate value (Chang et al., 2020; Halaszovich & Kinra, 2020; Koh et al., 2018).

Of the six subcategories, infrastructure scored the highest in spurring logistics activities across borders (Chang et al., 2020; Halaszovich & Kinra, 2020). Better infrastructure corresponded to lower transportation costs, improved efficiency, and positive economic consequences (Chang et al., 2020). While reviews called for infrastructure upgradation to trigger economic growth, they also advocated for investment in national road infrastructure to overcome national transportation system obstacles that limit international business activities (Ding et al., 2022; Halaszovich & Kinra, 2020).

In the relationship between LPI and transportation costs, findings were collectively in agreement that higher logistics aggregate value meant lower logistics transportation costs and higher export levels (Chang et al., 2020; Panichakarn & Pochan, 2023). This means that logistics efficiency informed by the chosen mode of transportation had a direct positive effect on transportation costs, which translated into improved local and international trade (Chang et al., 2020; Ding et al., 2022; Panichakarn & Pochan, 2023). Ding et al. (2022), for example, used China's LPI to explore the interrelations between logistics performance and export competitiveness. Results established that when the efficiency of logistics and transport was high, transportation costs expressed per unit distance were low, and with a decrease in logistics and transportation costs, demand for domestic products by foreign markets increased, as did the export value, which was expressed in terms of domestic prices. Ding et al. (2022) further noted that the reduction of transportation costs by approximately 50% had a fivefold increment in the number of transactions made.

LPI also considered corruption an ethical issue. Koh et al. (2018) assessed the relationship between corruption, trade facilitation, and LPI in Asian countries. The findings indicated that corruption significantly impacted the composite LPI and each of the six dimensions of LPI. This concurred with other studies that argued that while corruption is regarded as a "grease the wheel" factor to facilitate trade and efficiency by circumventing bureaucratic legal frameworks, corruption can be regarded as "sand in the wheels" since the grease money leads to an increase in the cost of trade, leading to an eventual burden on the populace (Koh et al., 2018; Nayak et al., 2024).

The nexus between LPI and policy and governance was also underscored. Reviews established that policy design and government effectiveness impacted logistics activities (Nayak et al., 2024; Nguyen & Le, 2024). Governance inefficiencies create room for unethical issues such as corruption that negatively impact logistics activities. Effective governance in cross-border operations creates transparency of regulatory authorities, which impacts law enforcement, leading to increased international trade activities (Koh et al., 2018; Nguyen & Le, 2024). It was further established that an inefficient legal framework impacted financial crises by decoupling logistics activities. Countries facing political constraints had extended financial crises in terms of debts and weak currencies, which led to a low-value LPI and consequently poor logistics activities.

However, some studies argued that, as much as they appreciated the use of LPI as a unifying factor in measuring the effectiveness of the logistics sector, it was not without notable limitations and hence did not utilize it (Nayak et al., 2024; Nguyen & Le, 2024). They pointed out that LPI was unifying at the international level but was not generally suitable to measure domestic or in-country performance. They therefore went a step further to devise the in-country (ILPI), which is based on the perceptions of international freight forwarders and other across-border logistics professionals, and the national LPI (NLPI), which is based on feedback from domestic logistics freight forwarders. Nayak et al. (2024), through an extensive literature search and empirical analysis, identified six dimensions of the ILP index in their order of importance from the most significant to the least significant: quality of infrastructure, economic, telecommunication infrastructure, physical infrastructure, social, and environmental dimensions. Nguyen and Le (2024) borrowed from Ekici et al. (2019) in the construction of an NLPI and used the five dimensions of infrastructure, market size, innovation, education and training, and technology readiness. Their argument was that the unifying factors proposed in the LPI may not necessarily cut across both developed and developing nations since the primary area of focus may differ.

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Table 1: Propensity to use the logistic performance index as a measure of logistics performance

| Title | Authors/publication year | Country (s) | Sample size | Yr range | Methods Used | LPI Measure |
|---|---|---|---|---|---|---|
| Impacts of regional integration and maritime transport on trade: with special reference to RCEP | (Chang et al., 2020) | Singapore, Malaysia, Indonesia, etc. | 16 countries | 2007, 2010, and 2015 | Gravity Model | Linear shipping connectivity<br>Logistics performance index<br>Trade performance |
| The double-edged resource-based view of logistics performance and governance in Asian countries | (Koh et al., 2018) | Afghanistan, Nepal, Indonesia, Mongolia, etc. | 26 countries | 2007- 2014 | Static Linear Panel Model | Corruption<br>LPI<br>Governance |
| The impact of distance, national transportation systems, and logistics performance on FDI and international trade patterns: Results from the Asian global value chains | (Halaszovich & Kinra, 2020) | Cambodia, Laos, etc. | 22 countries | 2007, 2010, 2012 | Gravity Model | Distance<br>The national transportation system<br>LPI<br>FDI<br>Trade–Imports and exports |
| Does Cross-Border Logistics Performance Contribute to Export Competitiveness? Evidence from China Based on the Iceberg Transport Cost Model | (Ding et al., 2022) | China | 10 countries | 2012-2018 | Iceberg transport cost model | LPI<br>Logistics efficiency<br>Costs<br>Export level<br>Export competitiveness |
| Financial crises and national logistics performance: Evidence from emerging and developing countries | (Nguyen & Le, 2024) | Emerging nations | 100 | 2007- 2017 | Dynamic Panel Data Model | Financial crises—banking, currency, and debt crises<br>National LPI<br>Infrastructure, market size, education, and training |
| Development of an in-country logistics performance index for emerging economies: a case study of Indian states | (Nayak et al., 2024) | India | 21 Indian states | 2012-2018 | Quintile and Principal Component Analysis | In country LPI<br>Physical infrastructure<br>Quality<br>Telecommunication<br>Social index<br>Economy |
| Analysis of the efficiency of land transport connectivity for international trade between Thailand and China | (Panichakarn & Pochan, 2023) | Thailand<br>China<br>Vietnam<br>Laos | 126 informants | | Time-cost-distance Analysis | LPI – time, cost, distance<br>Trade efficiency |

## Green Logistics and Trade Promotion

Reviewed studies on green logistics and trade promotion collectively emphasized the sustainability aspects of the TBL framework, which measures an organization's success in three key areas: environmental, economic, and social sustainability (Tornatzky, 1990) (Fig. 3). Most of the reviews leaned more on the environmental sustainability aspect of the logistics firms. The findings collectively indicated that logistics activities had an impact on environmental degradation through emissions, ecological hazards, and waste generation (Liu et al., 2018; Sheikh et al., 2023; Yang et al., 2024). There is a need for the integration of sustainability strategies to reduce the carbon footprint and minimize pollution. This requires the adoption of eco-friendly logistics practices to improve logistics performance and protect the environment.

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Liu et al. (2018), for example, appreciated the crucial role played by green supply chain management in environmental sustainability. The scholars modeled the interrelationships between logistics performance and environmental degradation. Using data from 42 Asian countries between 2007 and 2016, the findings indicated a positive nexus between logistics performance and environmental degradation. Some subcategories of LPI, for example, international shipment decreased $CO_2$ emissions, while logistics activity timeliness intensified $CO_2$ emissions. The study called for concerted efforts to encourage green logistics in the sampled nations to ensure environmental protection.

Similarly, Lu et al. (2019) attempted to construct an environmental LPI (ELPI) to assess green transportation and logistics performance. The findings established a strong correlation between ELPI and LPI. Generally, countries with high values of LPI had high values of ELPI. High ELPI values implied a reduction in $CO_2$ emissions and fossil fuel consumption, resulting in greener transportation, high trade volumes, economic growth, and trade promotion (Liu et al., 2018; Sheikh et al., 2023; Subramanian et al., 2014). Sheikh et al. (2023) further noted that with maritime logistics accounting for approximately 90% of international trade in volume, there was a need to observe cost efficiency, fuel and emission efficiency in order to achieve environmental sustainability whilst improving the port's overall competitiveness and functionality of maritime logistics.


Figure 3: Concept of the TBL Framework
Source: Zhang et al. (2024)

Regarding social sustainability, there was a consensus on the role of the government in promoting green transportation and overall business sustainability (Yang et al., 2024; Yingfei et al., 2022). Reviews acknowledge the impact of logistics activities on environmental degradation. However, the question that begs is "What is the government's role in curbing the vice?" Different strategies have been fronted with the inclusion of government tax policies and adoption of electric commercial vehicles (ECVs), among others. Most economists have advocated for policies such as a carbon tax and Cap-and-trade (C&T) to curb carbon emissions. The carbon tax policy is a fee levied by the government for each ton of carbon emitted, which encourages companies to reduce emissions when the cost of reduction outweighs the cost of tax payment. C&T, on the other hand, involves the establishment of an initial maximum level of carbon emission, which is referred to as the carbon emission quota.

Reviews recommended for the government role in implementing the two strategies, whose uptake currently is slow, and the inclusion of purchase subsidies and the availability of charging ports for ECVs (Subramanian et al., 2014; Yang et al., 2024; Yingfei et al., 2022). Yang et al. (2024), while using 52 restaurant owners in Shenzhen, China, investigated the influence of government policies on the adoption of EVCs, noted that the adoption is crippled by challenges such as high initial purchase costs, extended charging periods, degradation of the battery, and limited range. The study advocated for the government to combine C&T mechanisms with purchase subsidies to encourage ECV adoption and reduce emissions.

Government policies also play a crucial role in the allocation of resources for infrastructural development (Liu et al., 2018). This entails transportation networking to sustain imports and exports, and a telecommunication network system necessary for information exchange among others. Bold quality infrastructure bolsters communication among supply chain participants, leading to financial performance and enhancement of international trade (Van Vo & Nguyen, 2023; Yingfei et al., 2022). On the economic sustainability, the achievement of both environmental and social sustainability leads to economic sustainability of cost savings, increased market share, and profit growth (Chien & Shih, 2007). Yingfei et al. (2022), for instance, adopted a cross-sectional survey to investigate the relationships between green logistics performance and business performance in China. The results established a positive relationship between infrastructure and green logistics performance, which had a beneficial effect on the environment, services trade, and firm performance.

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Table 2: Green logistics and trade promotion

| Title | Authors/publication year | Country (s) | Sample size | Anchoring Theories | Subject unit | Green transportation and trade promotion |
|---|---|---|---|---|---|---|
| A comprehensive performance measurement model for maritime logistics: a sustainability and policy approach | (Sheikh et al., 2023) | Bangladesh | 76 | TBL | Academicians<br>Logistics managers | Port performance<br>Shipping connectivity<br>Hinterland logistics<br>Sustainability and resilience |
| Effectiveness of policies for electric commercial vehicle adoption and emission reduction in the logistics industry | (Yang et al., 2024) | China | 52 | Time Windows<br>Model | Restaurant owners | Government policies<br>Carbon tax policy<br>Cap and trade mechanism<br>Adoption of electric commercial vehicles |
| Green logistics performance and infrastructure on service trade and environment-Measuring firm's performance and service quality | (Yingfei et al., 2022) | China | 335 | Logistics theory<br>New trade theory | Economists<br>Financial analysts<br>Accountants | Green logistics performance<br>Infrastructure<br>Service trade and the environment<br>Firms' performance<br>Service quality |
| Green Transportation and Logistics Performance: An Improved Composite Index | (Lu et al., 2019) | Sub-Saharan Africa<br>Asia | 112 countries | - | | LPI<br>Green transportation<br>$CO_2$ emissions<br>Oil consumption<br>Environmental LPI |
| The relationship between the environment and logistics performance: Evidence from Asian countries | (Liu et al., 2018) | Asian countries | 42 countries | Green supply chain framework | | Logistics performance<br>Environmental degradation<br>LPI<br>$CO_2$ emissions<br>Trade openness |
| Integration of logistics and cloud computing service providers: Cost and green benefits in the Chinese context | (Subramanian et al., 2014) | China | 236 | Diffusion of the Innovation theory | Small- and medium-sized logistics providers | Perceived green benefits<br>Cost benefits of the integration<br>Cloud computing |
| Greening the Vietnamese supply chain: The influence of green logistics knowledge and intellectual capital | (Van Vo & Nguyen, 2023) | Vietnam | 142 | Absorptive capacity theory<br>RBV | Business managers | Green logistics performance<br>Environmental performance<br>Green intellectual capital<br>Green knowledge exploitation |

## Logistics Eco-innovation and Trade Promotion

With the prevailing worldwide environmental degradation due to various human activities, many countries have embraced innovation as a strategy toward environmental protection by devising ways of reducing emissions while retaining a competitive edge. This section sought to establish the level of eco-innovation embracement in the logistics sector and how the embracement relates to trade promotion in developing nations. The diffusion of innovation theory (DOI), which seeks to establish how firms adopt innovation (Rogers, 2003), guided this section. The diffusion process in the model explains the preceding steps for an innovation to be incepted,

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for example, through cost-benefit analysis, which helps in decision-making on whether to adopt an innovation (Atkin et al., 2018). The reviewed studies were grouped into three broad thematic areas: digitalization—the conversion of information into a digital format that can be computer processed; technological innovation—new technologies introduction or improvement of the existing ones; and smart logistics—the application of both digital technologies and data analytics to enhance logistics performance (Ridwan et al., 2024; Setthachotsombut et al., 2024; Wang et al., 2024).

Digitalization: There was a consensus on the crucial role played by the digitalization of trade in border control measures, efficiency, and trade management processes (Ridwan et al., 2024; Zhao et al., 2023). Digitalization reduces trade costs, fortifying the resilience of international supply chains. In addition, digitalization enables businesses to access a greater number of international connected suppliers and consumers using online platforms. Wang et al. (2024), for example, established the effect of the application of digital technology on the green products export of a firm while using data from Chinese listed firms. The scholars underscored the role of artificial intelligence and the digital economy in economic growth gains and sustainable development. A significant positive relationship between digital technology application and green product export was established.

Organizations with advanced ICT digital platforms such as ERP, AI, and cold services incorporated in their logistics systems enhance communication between actors in the sector (Coll & Straube, 2025). With digital connectivity and internet service utilization, exporting firms gain through time and cost reduction aspects related to border procedures as well as documentation. There was also a notable improvement in the quality of trade, transport infrastructure, logistical services, and the overall performance of the logistics firm. Ridwan et al. (2024), for instance, in an attempt to establish the relationship between financial development and trade performance as drivers toward Vision 2063 attainment in Africa, incorporated digitalization and transport services in the model. A positive interrelation between trade performance and digitalization, market size, and trade openness was noted.

Technological innovation (TI): Technological innovation has led to the efficiency and improvement of activities in the logistics sector (Du & Li, 2022). Through TI, firms are able to manufacture and export high-tech, eco-friendly products, thereby increasing their market share, profitability, and economic growth (Liu et al., 2024; Ridwan et al., 2024; Zhao et al., 2023). Zhao et al. (2023) investigated the impact of the logistics industry on global value chain promotion in China, including the role of technological innovation. Technological innovation, human capital, and logistics infrastructure positively influenced the global value chain. The paper recommends that the overall improvement of logistics systems would ultimately lead to an optimized value chain that would ensure smooth circulation both at home and abroad.

TI has also introduced innovative cities that play a key role in ecological protection worldwide (Fig. 4). Their focus is on improving energy efficiency, reducing pollutants, and improving environmental quality (Du & Li, 2022). Du and Li (2022) established the relationships between innovative city building and green logistics efficiency promotion in China. Their findings established a significant relationship between innovative cities and green logistics efficiency. The implementation of the innovative cities pilot policy was also deemed key in driving green logistics efficiency.

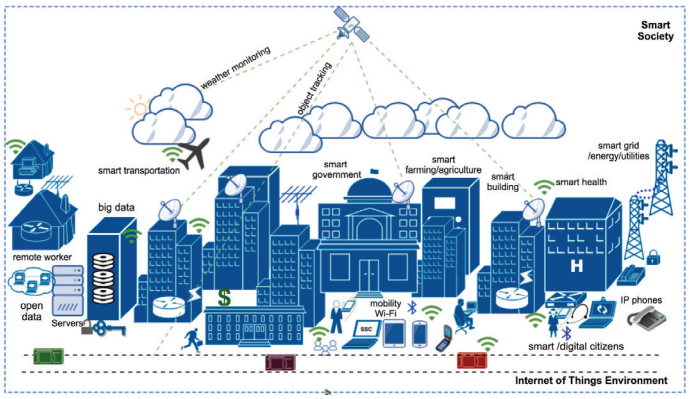


Figure 4: Illustrative figure of a model smart city
Source: Inuwa and Das (2024)

Smart Logistics Policy (SLP): Smart logistics emerged as a result of the need to optimize logistics activities of the flow of goods, resources, and communication along the supply chain with the help of digital technologies (Liu et al., 2024; Uckelmann, 2008). Government policies play a crucial role in the development of smart logistics. With government support, there is the formulation and implementation of policies that foster smart logistics. The policies aim at embracing technological opportunities, reducing pollutants, and improving the overall competitiveness of the firm. The reviews collectively underscored the role of SLP in influencing production, improving transportation, distribution, and smart warehousing (Liu et al., 2024; Setthachotsombut et al., 2024; Wang et al., 2024). The end results of the reduction of errors, complexity, cost, labor, and enhanced operational efficiency lead to a positive firm's competitiveness (Du & Li, 2022; Setthachotsombut et al., 2024).

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Table 3: Logistics eco-innovation and trade promotion

| Title | Authors/publication year | Country (s) | Sample size | Year range | Adoption barriers | Logistics innovation and trade promotion |
|---|---|---|---|---|---|---|
| Investigating the asymmetric effects of financial development on trade performance in Africa: Can digitalization, transport services, and regulatory quality drive the vision of 2063? | (Ridwan et al., 2024) | South Africa<br>Egypt<br>Morocco<br>Nigeria<br>Algeria | | 1996-2022 | Cyber insecurity<br>Fraud<br>Financial theft | Financial development<br>Digitalization<br>Transport service<br>Regulatory quality<br>Trade performance |
| Effect of the logistics industry on the promotion of China's position in the global value chain: An international trade perspective | (Zhao et al., 2023) | Asian countries | | 1995-2018 | | Human capital<br>Technological innovation<br>Logistics infrastructure<br>National economic development<br>Global value chain |
| The implications of smart logistics policy on corporate performance: Evidence from listed companies in China | (Liu et al., 2024) | China | | 2012-2017 | Financial constraints<br>Stakeholder conflicting interests | Smart logistics policy<br>Firm performance |
| Digitalization of interorganizational communication in the East African food industry | (Coll & Straube, 2025) | Ethiopia<br>Rwanda<br>Tanzania | 17 | | Lack of technical know-how<br>Cost implication<br>Face-to-face culture | Logistics network structure<br>Communication digitalization<br>International trade |
| Logistics business management of a provider in Thailand with smart logistics | (Setthachotsombut et al., 2024) | Thailand | 400 | | Obsolete legal structure<br>Resistance to change<br>Financial constraint | Smart logistics (SL) business management<br>People management SL<br>Rooms and working space SL<br>Administration and management of SL<br>Innovation dynamics<br>Trade performance |
| Does innovative city building promote green logistics efficiency? Evidence from a quasi-natural experiment with 285 cities | (Du & Li, 2022) | China | 285 | 2005-2019 | Lack of policy alignment<br>Lack of government support | Green logistics efficiency<br>Policy implementation<br>Green technology innovation |
| Going "green trade": Assessing the impact of digital technology application on green product exports. | (Wang et al., 2024) | China | 622 | | Financial constraints<br>Technical barriers<br>Green trade restrictions | Digital technology application<br>Green product export<br>Environmental regulation<br>Technology effect<br>Market expansion |

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## Discussion

The search established considerable ease in obtaining published articles from China compared to any other developing nation. This observation concurs with that of Halog and Anieke (2021) that although research in environmental sustainability has gained impetus in the recent past, slow growth has been evidenced in developing nations apart from China. Out of the 21 reviewed papers, seven were specifically from China, five from Asian countries 5, Thailand 1, three from Africa 3, three from emerging nations 2, Bangladesh 1, Vietnam 1, and one from India. It can therefore be deduced that, in terms of literature, as compared to Asian countries, Africa is lagging behind, and this calls for concerted efforts toward research improvement. The slow growth in Africa, which is attributed to both infrastructural and social challenges such as bottlenecked port operations, poor road quality, political and security instability, and inadequate rail facilities, among others, also calls for action by the concerned leaders and policy makers (Adewole & Struthers, 2018).

The review established a notable inclination to use LPI as a measure of logistics activities in various firms and countries. Different studies have established the interrelationships between myriad dimensions in the logistics sector, such as liner shipping connectivity, trade performance, full container load, corruption, governance, foreign direct investment, financial crises, and LPI. However, it was noted that logistics performance in most of the developing countries is still lacking. For instance, a comparison of performance from the 2023 World Bank's LPI ratings for the top 20 countries in the developed nations, Asia, and Africa was carried out. While developed nations had an average score of 3.96, Asia scored 3.27, while Africa scored 2.72. This thus calls for the need to improve logistics activities in developing nations, especially in Africa.

While LPI is a benchmarking tool in measuring logistics performance, some reviews noted its notable limitations, and scholars argued that it might not adequately fit to measure national or in-country logistics performance. They argued that while it was paramount to have a unifying logistics index at the international level, for effective policies and reforms at the national level, it was advisable to use performance indicators that were more relevant to an individual nation instead of generalization. This concurs with some studies that established that while low-income nations concentrated on logistics infrastructure and facilitation of transport, countries in the middle-income earners' band focused on efforts toward improvement of logistics skills, services, and trade regulations. On the other hand, high-income nations were more focused on the state of green logistics and information systems.

It was also established that since the unifying LPI is based on web surveys and qualitative information derived from both logistics and freight forwarding experts, there was a risk of bias because of their subjective norms. Respondents' attitudes and cognitive ability could affect the qualitative data negatively. Therefore, considering these limitations, some scholars failed to use the World Bank's devised LPI and suggested other models that could be utilized in measuring LPI for specific nations through the use of established indicators that were specific to a given nation, while utilizing secondary data.

On the link between green transportation and trade promotion, the reviewed articles first noted the environmental degradation effect of logistics activities and then collectively underscored the need to regulate logistics activities to protect today's and future generations. Green logistics was connected to the reduction of $CO_2$ emissions, greenhouse gases, and pollution, which had an ultimate positive effect on both local and international trade. How do firms achieve green logistics? The reviews fronted various strategies, which included the implementation of environmental policies such as tax levies and carbon prices, and purchase subsidies for electric vehicles. However, vices such as corruption were mentioned as one of the social evils that derail logistics activities, leading to higher trade costs and eventual cost increases of the end products. This lowers the competitiveness of the logistics firms. As much as the reviews called on firms to take individual responsibility in promoting environmental protection, there were calls for government facilitation through offering purchase subsidies and developing policies that favor logistics firms.

Embracement of logistics eco-innovation and its role in trade promotion was also evidenced in the reviewed articles. Innovative strategies used by different companies in different nations included digitalization, implementation of smart logistics policy, and adoption of innovative cities. Innovative cities are directly correlated with green logistics through the prevention of pollution, reduction of emissions, and sustainable business performance. While innovative technology adoption presented notable advantages, it was marred by a couple of adoption challenges: while most of the reviews listed financial constraints, others included cybersecurity threats, lack of government support in policy alignment, resistance to change due to rigid organizational culture, and lack of technical know-how. This, therefore, calls for concerted efforts by different key actors in the logistics industry to encourage and adopt technological innovations.

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## Limitations

The systematic review has some limitations, even though it provides notable insights regarding logistics performance and trade promotion. First, the search criteria used three databases of Scopus, Web of Science, and Science Direct. Though the search was rigorous, there might be chances of excluding some relevant studies due to variations in terminology and indexing methods. In addition, the search could have missed other valuable papers not published within the scope of the three databases. Second, the review relied on English-language peer-reviewed articles published between 2000 and 2025. Language and publication bias in terms of time frame may have been experienced. Third, the reviewed papers were drawn from different countries, used different sample sizes, different data collection methods, and diverse use of data analysis methods such as gravity models, linear panel models, and transport ice berg models, among others. While these added to the robustness of the study, they, however, curtailed the generalizability capacity of the findings. Lastly, although different countries were included in the review, the study did not include cross-country comparative frameworks. However, these limitations present solid ground for continued research in the field of logistics performance and trade promotion.

## Conclusion

There is an extensive propensity to adopt and use LPI as a measure of logistics performance by different scholars in developing nations. However, it was noted that the World Bank's LPI had some limitations that curtailed some scholars from adopting it and thus devised and proposed other LPIs meant for specific reasons, e.g., specific regions. An intricate interplay between green transportation and trade promotion was also evidenced. The reviewed articles were anchored on different theories related to green transportation studies, such as the Resource-Based View, New Trade Theory, and Green Supply Chain framework. However, the review used the TBL framework to broadly categorize green transportation and firm performance into three categories: economic, environmental, and social sustainability. The role of green transportation in $CO_2$ reduction, production of green products, reduction of greenhouse gas (GHG) emissions, governance, policy framework formulation, firm performance, and firms' competitive advantage were all enshrined in the three subcategories of the TBL framework.

Innovation also played a crucial role in environmental protection, especially through pollution and emissions prevention. Digitalization, adoption of smart logistics policies, and promotion of innovative cities were some ways through which this was achieved. The diffusion of innovation theory, which aids in decision-making on whether to adopt a technology innovation, best guided this section. Through a five-step process of knowledge, persuasion, decision, implementation, and confirmation, an organization is able to decide whether to accept or reject an innovation. This was evidenced in the reviews through an analysis of barriers to innovation adoption, such as financial constraints and lack of policy frameworks in favor of technology and an eventual analysis of the benefits derived from the adopted technologies, such as the positive impact on the environment and the firm's performance through cost reduction, labor reduction, minimization of errors and overall operational efficiency improvement. However, the study suggests that future work should develop validated, country-level LPI variants that capture green innovation impact on trade in low-income regions.

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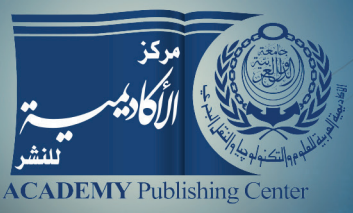


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