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# APPLICATIONS OF SUSTAINABLE PRACTICES IN MARITIME LOGISTICS SECTOR

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## ABSTRACT

*Maritime logistics is a cornerstone of international trade, yet the transition toward sustainable operations remains difficult, especially in developing and emerging economies. Although many global studies discuss green technologies and regulatory initiatives, there is still limited understanding of how these ideas are implemented in regions of the Global South and what obstacles they face. Typical challenges include high capital requirements, fragmented or unstable regulatory environments, and insufficient infrastructure to support sustainable technologies. This study conducts a systematic examination of how sustainable practices are applied within the maritime logistics sector. It pursues four objectives: (1) to identify and classify the barriers that influence the application of sustainable practices; (2) to map the indicators used to evaluate the extent of sustainability adoption; (3) to review trends and descriptive patterns in the implementation of sustainable practices; and (4) to uncover major research gaps in the existing literature. A systematic literature review (SLR) was carried out following the PRISMA 2020 guidelines, covering 43 peer-reviewed publications issued between 2015 and 2025. The review shows that financial constraints, technological and operational limitations, and regulatory issues are the most frequently reported barriers to sustainable practices in maritime logistics. It also highlights key performance indicators such as reductions in carbon emissions, improvements in energy efficiency, and the uptake of renewable energy as central measures of sustainable performance. Moreover, the findings point to an increasing emphasis on digitalization, cleaner energy solutions, and other green technologies, particularly in large port settings. Overall, the study offers an integrated picture of current sustainable practices in*

*maritime logistics and outlines directions for future research aimed at strengthening the sector's transition toward more sustainable operations across different regions.*

**Keywords**: Adoption, Barriers, Maritime Logistics, Maritime Sustainability, Sustainable Practices

## 1. Introduction

### 1.1. Background

An estimated 90% of world merchandise trade is carried by sea, which makes maritime logistics a core element of the global economy [UNCTAD, 2023]. Ports act as strategic nodes where raw materials, components and finished products are transferred between sea and land transport, enabling production and consumption in sectors such as agriculture, manufacturing and energy while contributing significantly to national income [World Bank, 2022]. At the same time, growing awareness of climate change and environmental degradation has brought the sustainability performance of this sector under close scrutiny. Maritime transport has historically depended on fossil fuels, which are associated with high greenhouse gas emissions, marine pollution and the depletion of natural resources [Karagkouni and Boile, 2024]. Congested port operations and overstretched infrastructure intensify these impacts, reinforcing the urgency of transitioning toward more sustainable practices.

According to the International Maritime Organization (IMO), international shipping is responsible for roughly 2–3% of global carbon dioxide emissions [IMO, 2022]. In response, industry stakeholders and regulators have begun to promote a range of mitigation measures, including the introduction of lower-carbon and alternative fuels (e.g. LNG and hydrogen), increased use of renewable energy sources such as solar and wind power, and investments in energy-efficient port and vessel infrastructure. These technological shifts are often supported by digital innovations such as the Internet of Things (IoT), artificial intelligence (AI) and blockchain to optimise operations, cut fuel use and improve overall efficiency [Mba, 2024]. Such initiatives are intended to support broader international agendas, including the IMO's

decarbonisation strategy and the commitments of the Paris Agreement [UNFCCC, 2015].

Despite these developments, the transition to sustainable maritime logistics is uneven and faces multiple obstacles. High upfront capital requirements, inadequate facilities for alternative fuels, and gaps in regulatory frameworks slow down large-scale deployment of green solutions [Bielenia et al., 2024]. Fragmented governance structures, delays in policy enforcement and shortages of specialised technical expertise further limit the uptake of technologies such as LNG and hydrogen propulsion [Karagkouni and Boile, 2024; Bielenia et al., 2024]. Global policy frameworks including the IMO's climate targets and the United Nations Sustainable Development Goals (SDGs) provide a clear direction for change [UN, 2015; IMO, 2022], yet the pace and depth of implementation differ markedly across regions and port systems. In Sri Lanka, for instance, pilot efforts such as solar energy initiatives at the Port of Colombo and energy-efficient lighting at private terminals demonstrate interest in sustainability, but their expansion has been constrained by high costs, infrastructure limitations and weak regulatory support [Sri Lanka Ports Authority, 2023]. Against this backdrop, the present systematic literature review examines how sustainable practices are being applied in maritime logistics, with a particular focus on the barriers, indicators and trends that shape progress toward a more sustainable sector.

### 1.2. Objectives of the Review

This review seeks to systematically synthesise existing research on the use of sustainable practices in the maritime logistics sector. In line with this aim, the specific objectives are:

1. To identify and classify the main barriers that influence the implementation of sustainable practices in maritime logistics.
2. To compile and examine the measurement indicators used to evaluate the level of adoption of sustainable practices.
3. To explore the prevailing trends and descriptive characteristics associated with sustainable practices in the maritime logistics sector.

4. To pinpoint key research gaps related to sustainable practices in maritime logistics and highlight areas that require further investigation.

### 1.3. Research Problem and Gap

Although sustainability has become an important theme in maritime logistics research, the existing evidence on how sustainable practices are adopted and embedded in operations remains fragmented, particularly in developing economies. Many studies discuss green shipping technologies, energy-efficient port operations, and environmental regulations at a global level, yet they pay comparatively little attention to the specific constraints and opportunities encountered in regions such as the Global South. Challenges including high initial investment requirements, policy uncertainty, inconsistent regulatory enforcement and limited infrastructure for alternative fuels and energy-efficient technologies are mentioned across the literature but are seldom analysed in a comprehensive and integrated manner. In addition, there is limited empirical work on how different actors in maritime logistics such as port authorities, terminal operators, shipping companies, freight forwarders and exporters adjust their strategies and capabilities to incorporate sustainability into everyday practices. The absence of such holistic analyses restricts the development of practical frameworks and policy recommendations that reflect the realities of ports and maritime logistics systems in both developed and developing contexts. This review therefore addresses a dual gap: the lack of consolidated evidence on barriers, indicators and trends in sustainable practice, and the shortage of studies that capture the specific experiences of maritime logistics stakeholders in countries such as Sri Lanka and other parts of the Global South.

### 1.4. Methods

The study adopts a systematic literature review (SLR) to explore how sustainable practices are applied within maritime logistics, using the PRISMA 2020 guidelines to structure the review process. Relevant publications were identified through targeted searches in major academic databases, including ScienceDirect, Emerald Insight, ResearchGate, and Google Scholar, using combinations of keywords such

as “adoption,” “barriers,” “maritime logistics,” “maritime sustainability,” and “sustainable practices”. The search was restricted to peer-reviewed articles published between 2015 and 2025. After removing duplicate records and screening studies against predefined inclusion and exclusion criteria, a final sample of 43 articles was retained. These studies were examined through qualitative synthesis and thematic analysis in order to map key trends, barriers, indicators and opportunities related to sustainable maritime logistics.

### 1.5. Overview of the Main Results

The review shows that the adoption of sustainable practices in maritime logistics is constrained by several recurring factors, notably limited financial resources, technological and operational shortcomings, and regulatory or policy-related obstacles. Large initial investments required for green technologies, together with legacy systems, tend to slow the uptake of digital and low-carbon solutions, while fragmented or unstable regulations further impede progress. In terms of performance measurement, studies most frequently refer to indicators such as reductions in carbon emissions, improvements in energy efficiency and the extent of renewable energy use. The literature also points to a growing interest in smart and data-driven tools including automation and Internet of Things (IoT) applications to enhance operational efficiency and lessen environmental impacts. Nonetheless, evidence of the long-term economic consequences of these sustainability initiatives remains limited, particularly for developing economies. This underlines the need for additional research on cost–benefit outcomes and comparative analyses across different regions and port systems.

## 2. Literature Review

The body of literature reviewed, covering the period from 2015 to 2025, largely examines how sustainability is pursued within the maritime logistics sector. Many contributions evaluate the introduction of green technologies, improvements in energy performance and approaches to cost optimization in port operations. For instance, Sampath et al. [2022] describes Sri Lanka’s growing reliance on renewable energy sources such as wind and solar power as a means of cutting carbon emissions, while Weerasinghe et al. [2023] underlines the role of energy-efficient

equipment and systems in port activities. Fernando and Wakkumbura (2023) discuss the impact of geopolitical tensions on, while Kumar et al. (2022) focus on the adoption of the Blue-Green economic model to balance economic growth with sustainability. Studies by Dharmasiri (2017) and Gunasekara et al. (2022) address the vulnerabilities of the maritime sector, emphasizing the need for port diversification and digital infrastructure to enhance resilience. Silva and Karunanayake (2023) explore the role of AI and IoT in improving sustainability, while Zhang et al. (2019) focus on port automation and green logistics technologies. Most studies used empirical analyses, including case-based evaluations and policy assessments, with qualitative methods such as interviews and expert reviews commonly employed in region-specific studies. Scenario-based modeling was also used to analyze the impacts of green practices in port operations.

## 3. Methodology

### 3.1. Data Sources

This study applies a systematic literature review (SLR) to investigate sustainable practices in maritime logistics, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to maintain transparency and reproducibility. The population of interest consists of peer-reviewed scholarly articles that examine maritime logistics and sustainability, including green technologies such as alternative fuels and renewable energy.

Structured searches were carried out in four major academic databases: ScienceDirect, Emerald Insight, ResearchGate and Google Scholar. The search strategy used combinations of the keywords **"adoption," "barriers," "maritime logistics," "maritime sustainability," and "sustainable practices"** in titles, abstracts and keyword fields. The time frame was limited to publications between 2015 and 2025 to capture recent and policy-relevant research, and only articles written in English and published in peer-reviewed outlets were considered.

In total, **266** records were initially identified. Following the PRISMA 2020 procedure, **10** duplicates were removed, and **74** records were excluded based on publication year, language or lack of peer-review

status. Screening of titles and abstracts led to the exclusion of a further **120** articles that were not directly related to sustainable practices in maritime logistics. Full-text screening then removed **4** inaccessible articles and **15** papers that did not meet academic credibility or methodological quality standards. This process resulted in a final sample of **43** peer-reviewed articles used for detailed analysis.

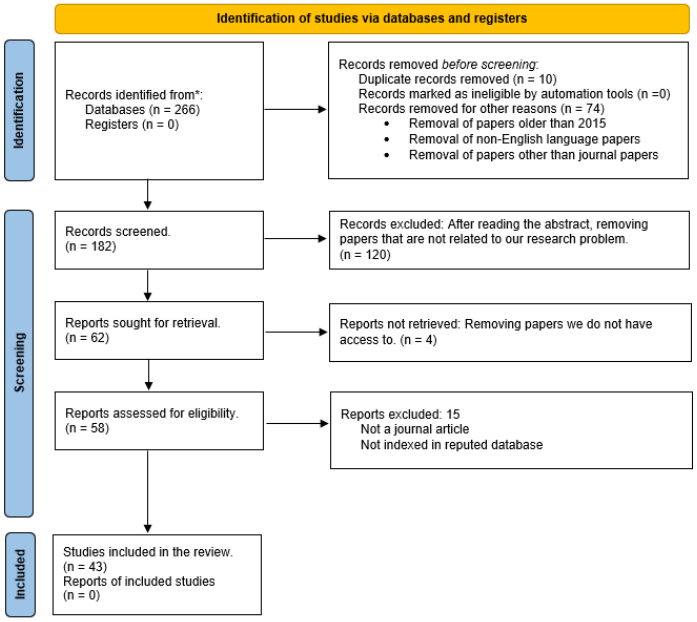


**Figure 1:** PRISMA Model

## 3.2. Data Analysis

### 3.2.1. Thematic Analysis

**a) Objective 1: Identification and categorization of barriers related to the applications of sustainable practices in the maritime logistics sector**

The first objective of this study was to identify and categorize barriers to adopting sustainable practices in maritime logistics. A systematic literature review of 43 peer-reviewed articles revealed common barriers, including financial constraints, technological limitations, policy and regulatory hurdles, and organizational resistance. Financial constraints stem from high initial costs of green technologies (Parhamfar et al., 2023), while technological limitations arise from outdated systems and slow adoption of smart technologies (Gunasekara

et al., 2022). Regulatory barriers, such as inconsistent policies and a lack of international coordination, also impede progress (Katuwawala & Bandara, 2021).

**Table 1:** Identification and Categorization of Barriers

| Barrier Type | Primary Causes (Indicators) | Explanation | Key Studies |
|---|---|---|---|
| Financial Constraints | High initial costs, lack of funding sources | High-front investment is required for renewable energy infrastructure and technologies. | Parhamfar et al. (2023) |
| Technological Limitations | Outdated infrastructure, slow adoption of smart technologies | Difficulty in integrating advanced technologies like IoT and AI due to legacy systems. | Gunasekara et al. (2022) |
| Regulatory Barriers | Inconsistent policies, lack of enforcement, and regional differences | Variations in sustainability regulations across regions lead to fragmented implementation. | Katuwawala and Bandara (2021) |
| Organizational Resistance | Cultural factors, lack of training, and reluctance to change | Resistance within organizations to adopt new practices and technologies. | (Referenced studies on internal resistance within organizations) |

### b) Objective 2: To compile and examine the measurement indicators used to evaluate the level of adoption of sustainable practices

The second objective of this study was to identify the measurement indicators used to assess the adoption of sustainable practices in maritime logistics. Key indicators include carbon emissions reduction, energy efficiency, waste reduction, and the integration of renewable energy. Studies like Parhamfar et al. (2023) use carbon footprint and energy consumption, while Sampath et al. (2022) emphasize renewable energy sources like solar and wind. Additionally, the adoption of smart

technologies, such as automation and real-time monitoring systems, is highlighted by Samarasinghe et al. (2024) as a key indicator of sustainability.

**Table 2:** Measurement Indicators

| **Measurement Indicator** | **Primary Focus (Indicator)** | **Explanation** | **Key Studies** |
|---|---|---|---|
| Carbon Emissions Reduction | Carbon footprint, emissions reduction | Evaluates the reduction in greenhouse gas emissions associated with port operations and logistics. | Parhamfar et al. (2023) |
| Energy Efficiency | Energy consumption, energy-saving technologies | Focuses on improving energy use in port operations through optimized processes and energy-efficient equipment. | Sampath et al. (2022) |
| Waste Reduction | Reduction in waste generation, recycling initiatives | Measures efforts to reduce waste, improve recycling, and minimize environmental impact in port operations. | (Referenced studies on waste reduction in ports) |
| Renewable Energy Adoption | Integration of solar, wind, or other renewable energy sources | Assess the use of renewable energy, such as solar and wind, to power port operations and reduce dependence on fossil fuels. | Sampath et al. (2022) |
| Smart Technologies Implementation | Automation, IoT, digital systems | Evaluates the integration of smart technologies like IoT and AI to optimize operational | Samarasinghe et al. (2024) |

| | |
|---|---|
| | efficiency and sustainability. |

### c) Objective 3: Trends and descriptive characteristics of sustainable practices in the maritime logistics sector

The third objective of this study was to analyze trends in sustainable practices in maritime logistics. The analysis shows a growing shift towards sustainability in response to regulatory pressure and environmental concerns. Ports are adopting green technologies like energy-efficient equipment, electric vehicles, and renewable energy. Global ports lead in implementing low-carbon technologies and improving efficiency. Fernando and Wijeratne (2023) highlight the rise of green port certification and smart technologies, such as AI-driven management and automation. The sector is also embracing circular economy models, waste reduction, and recycling, with sustainable practices increasingly viewed as a competitive advantage for attracting environmentally conscious investors (Sarjoon et al., 2021).

**Table 3:** Trends and Descriptive Characteristics

| Trend/Characteristic | Focus Area | Explanation | Key Studies |
|---|---|---|---|
| Green Technologies Adoption | Energy-efficient equipment, electric vehicles | The shift towards adopting energy-efficient technologies, such as electric vehicles and low-carbon equipment. | Fernando and Wijeratne (2023) |
| Renewable Energy Installations | Solar, wind, and other renewable energy solutions | Increasing the implementation of renewable energy sources in ports to reduce dependence on fossil fuels. | Fernando and Wijeratne (2023); Sarjoon et al. (2021) |
| Smart Technologies Integration | AI-driven management, automation, IoT | Ports are adopting smart technologies like AI, automation, and IoT to | Fernando and Wijeratne (2023) |

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|---|---|---|---|
| | | enhance operational efficiency and sustainability. | |
| Circular Economy Models | Waste reduction, recycling | Focus on reducing waste through recycling initiatives and applying circular economy models in port operations. | Sarjoon et al. (2021) |
| Competitive Advantage through Sustainability | Attracting environmentally conscious investors | Ports view sustainable practices as a competitive edge in attracting investors and stakeholders focused on environmental responsibility. | Sarjoon et al. (2021) |

**d) Objective 4: Identification of key research gaps in sustainable practices within the maritime logistics sector**

The fourth objective was to identify research gaps in sustainable maritime logistics. Key gaps include the lack of empirical data on the long-term economic impact and financial feasibility of renewable energy adoption at ports, limited comparative studies across regions with diverse infrastructure (Gunasekara et al., 2022), and insufficient research on the practical challenges of digitalization and smart technology integration in ports (Sampath et al., 2022). These gaps highlight the need for future research on financial impacts, technology integration, and regional variations in sustainability implementation.

**Table 4:** Research Gaps

| **Research Gap** | **Focus Area** | **Explanation** | **Key Studies** |
|---|---|---|---|
| Long-term Economic Impact of Sustainable Practices | Cost-benefit analysis, financial feasibility | Limited empirical data on the financial feasibility and long-term ROI of | (Gunasekara et al., 2022) |

| | | | |
|---|---|---|---|
| | | implementing sustainable technologies, like renewable energy, at ports. | |
| Standardization of Sustainability Metrics | Regional variations, standard metrics | Lack of standardized metrics to assess sustainability success across diverse geopolitical contexts, especially in developing countries. | Gunasekara et al. (2022) |
| Technology Integration Challenges | Digitalization, smart technologies | Need for more research on the challenges and barriers to adopting smart technologies and integrating them into existing port infrastructures. | Sampath et al. (2022) |
| Comparative Studies on Regional Sustainability Practices | Geopolitical differences, infrastructure limitations | Need for comparative studies that examine how sustainability measures are practiced across different regions, particularly in developing nations. | Gunasekara et al. (2022) |

## 4. Results and Discussion

### a) Year of Publication

Figure 2 shows the growing interest in sustainable practices within maritime logistics, with publications increasing significantly from 2020 onwards. Initially, studies from 2015–2018 averaged 2–3 per year, but starting in 2020, the trend grew, peaking in 2023 with 10 publications. This rise reflects global shifts toward green logistics and heightened attention to sustainability, renewable energy, and digital technologies in ports. By 2024, 75% of studies were published in the last four years, underscoring the urgency of addressing environmental challenges and

enhancing port efficiency, especially as Sri Lanka aims to meet global sustainability goals.

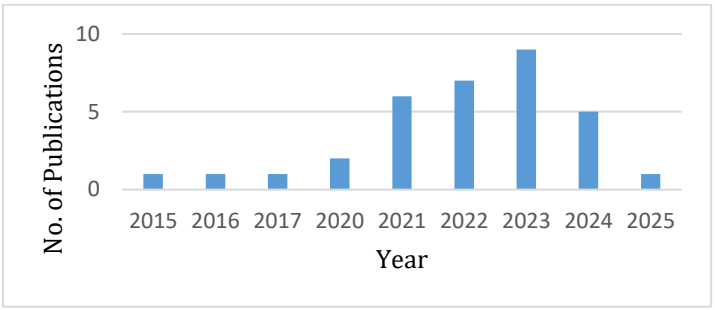


**Figure 2**: Year of Publication

**b) Study Methodologies**

Figure 3 shows that model-based approaches (30%) and documentary analysis (27%) were the most common methodologies in the literature, focusing on economic simulations, efficiency analysis, and policy evaluations. Theoretical analysis made up 15%, often developing frameworks for port competitiveness and sustainability. Empirical methods (12%) involved case studies, while interview-based methods (9%) gathered qualitative insights from stakeholders. Survey-based studies were the least used (6%). The results highlight a dominance of data-driven and document-based research, with opportunities for more empirical and stakeholder-focused studies in the future.

**c) Journals of Publications**

As illustrated in Figure 4, the majority of the reviewed articles appear in well-established, high-impact journals. The *International Journal of Logistics Management* accounts for the largest share, with **seven** papers. *Maritime Policy & Management* and the *Journal of Marine Science and Engineering* follow, contributing five and four articles, respectively. Other important outlets are the *Journal of Shipping and Trade* and the *Journal of Cleaner Production*, which add two and four publications.

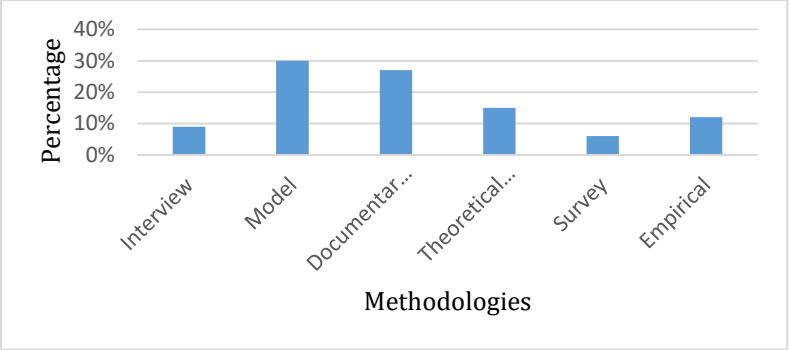


**Figure 3**: Study Methodologies

*Maritime Economics & Logistics* includes three articles in the final sample. In addition, titles published under Emerald Insight and Springer imprints contribute six and two papers, underscoring the strong engagement of these publishers in disseminating research on sustainable maritime logistics.

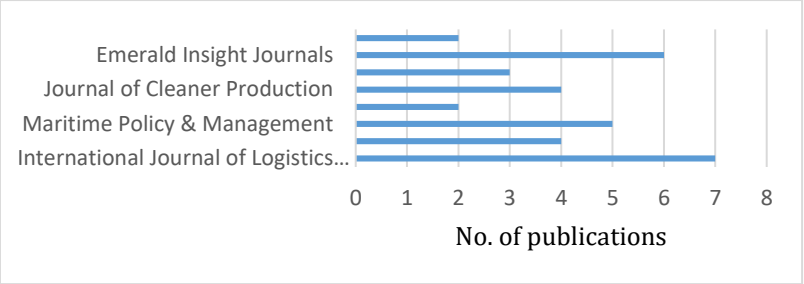


**Figure 4**: No. of Publications per Journal

### d) Geographical Focus

Figure 5 shows that Sri Lanka is the leading contributor to research on sustainable maritime logistics, reflecting its active role in maritime trade. The United Kingdom, the United States, and Germany are also key contributors. Other countries, such as India, Pakistan, Bangladesh, Nepal, Afghanistan, and China, have varying levels of participation, illustrating global interest in the sustainability of maritime logistics. The "Other Global Contributions" category encompasses a diverse range of international contributions, highlighting the widespread relevance of sustainability practices across the sector.

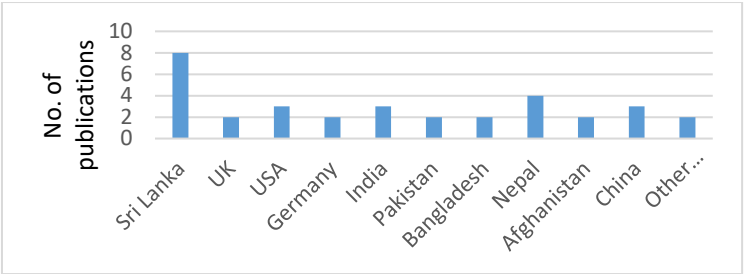


**Figure 5**: Geographical Distributions of Publications

## 5. Conclusions and Implications

This systematic literature review brings together evidence from 43 peer-reviewed articles published between 2015 and 2025, examining how sustainable practices are adopted and developed within the maritime logistics sector. The synthesis confirms a noticeable shift towards sustainability, yet it also shows that progress is uneven and often slow. Financial pressures, technological and operational constraints, and fragmented or weak policy frameworks repeatedly emerge as core obstacles to implementation. According to the reviewed studies, commonly reported sustainable practices include the use of renewable energy, energy-efficient port and terminal operations, and the deployment of smart and digital technologies to optimise logistics processes. At the same time, high upfront investment requirements, uncertainty about long-term returns and inconsistent regulatory support continue to limit large-scale adoption.

The review further indicates that the maritime logistics sector remains highly exposed to disruption, particularly in developing and trade-dependent economies such as Sri Lanka. Heavy reliance on a few gateway ports, notably Colombo, and on export-oriented industries like apparel and agriculture makes these economies vulnerable to shocks in global supply chains. Geopolitical tensions, climate-related events and infrastructure bottlenecks can quickly translate into operational delays and economic losses. From a policy perspective, the findings suggest that developing economies need stable and predictable regulatory frameworks for maritime decarbonisation, targeted financial instruments (such as concessional loans or public–private partnerships) to lower the cost of green investments, and sustained capacity-building for port authorities, regulators and logistics operators. Regional

cooperation and data-sharing between ports can also help smaller economies pool resources, harmonise standards and avoid fragmented approaches to sustainability.

For researchers, the results highlight the need for more empirical work on the long-term economic impacts of sustainable practices, comparative studies across regions and port types, and deeper analysis of how different governance arrangements shape sustainability outcomes in maritime logistics.

### 5.1. Recommendations and Paths for Further Research

Firms should invest in renewable energy systems, energy-efficient operations, and smart technologies like AI and IoT to improve supply chain visibility and mitigate sustainability risks. Policymakers need to strengthen policy frameworks, create incentives for green technologies, and encourage public-private collaboration. The global maritime sector should focus on standardizing sustainability metrics and data-sharing across trade corridors.

Key research gaps include quantitative impact assessments to measure the effects of renewable energy, cross-sector comparative studies in Sri Lanka to identify best practices, social impacts of sustainable port operations, AI forecasting for sustainability outcomes, and exploring governance models like public-private partnerships to support sustainability in Sri Lanka's maritime sector.

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