

SUSTAINABLE LOGISTICS PRACTICES AND SEAPORT OPERATIONAL EFFICIENCY IN THE MARITIME SECTOR: A LITERATURE REVIEW

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ABSTRACT

This study examines sustainable logistics practices and seaport operational efficiency in the maritime sector. The study employed a qualitative research design for the review. The study used a systematic literature review of 255 peer-reviewed studies sourced from Scopus, Web of Science, and IEEE databases. The study then utilised PRISMA 2020 framework for identification, screening, eligibility, and inclusion processes for selecting 132 studies for the proper review. Using a thematic analysis supported by triangulation and saturation, the study identified emerging research trends associated with the shift from an infrastructure to a digitally & environmentally integrated paradigm within the maritime sector. The study revealed dominance themes across the reviewed studies, which include digital technologies, green energy, automation, green port infrastructures, and port-hinterland integration. The study further uncovered significant disparities across regions. Europe emphasised more on sustainability issues, East Asia emphasised more on technological innovation, while Africa regions focused on establishing the most basic logistics efficiencies. However, study uncovers a significant gap between the pace of technological advances and the current operational realities of logistics operations in developing economies. Also, the study revealed lack of empirical evidence and real-world application in sustainable logistics practices. Hence, the study recommends greater emphasis on real-world implementation, and empirical evidence to bridge existing gaps and enhance global applicability of sustainable logistics practices in the maritime sector.

Keywords: Logistics, green energy, operational efficiency, seaport, sustainable logistics, maritime sector

1. INTRODUCTION

The function of seaports can be summed up by their continued significance as a key facilitator of international trade and economic development. The seaports provide access points through which goods are transported around the world via sea. They help improve global supply chain networks through their ability to move vast numbers of shipments around the world. This will have a significant impact on national productivity, trade competitiveness, and overall economic development of Nigeria (Kishore, Pai, Ghosh & Pakkan, 2024). Efficient seaports ensure efficient handling cargo, lower overall logistics costs, and increase the level of collaboration of all supply chain actors (Kishore et al., 2024; Xiao, Xu, Shu & Liu, 2024). All these factors make the operations of seaports critical elements of an efficient logistics operations and support increased productivity in the maritime sector. Nigerian seaports serve as regional logistics hubs by providing a link between maritime transport and inland distribution networks. Thus, enhancing the efficiency of Nigerian seaport operations will lead to improved efficiency in logistics systems, increased speed of cargo handling, and enhanced competitiveness of Nigerian international trade.

The last decade has seen sustainable logistics emerge as an important area of interest in the maritime sector due to increasing environmental concerns and the need for better supply chain management (Lafta & Aletaiby, 2025). Sustainable logistics are eco-friendly logistics operations that have minimal adverse impact on the environment, while achieving the maximum operational efficiency and making optimal use of available resources in the maritime sector (Xiao et al., 2024). Sustainable logistics include green transportation, energy-efficient infrastructures, digital logistics technologies, waste management systems, and eco-friendly operating practices for moving products (Kishore et al., 2024). These aspects of sustainable logistics are meant to help ensure that logistics-related activities contribute to the long-term economic growth of the maritime sector (Liu & Ye, 2026).

Port authorities worldwide are incorporating sustainable logistics into their business models due to increasing demand for their services, the pressures on the environment caused by climate change, and the capacity and resilience of the overall supply chain (Kishore et al., 2024; Xiao et al., 2024). Kishore et al., (2024) opined that environmental sustainability practices such as developing green ports, digitizing logistics systems, and implementing smart port technology assist in enhancing seaport productivity and operational efficiency. Also, innovative technologies (artificial intelligence, Internet of Thing, and digital logistics platforms) will ultimately change how seaports operate by enhancing transparency of cargo, implementing efficient vessel scheduling systems, and improving logistics coordination throughout the global supply chain (Alzate et al., 2024).

In spite of the recent growth of sustainability in the global maritime sector, there are still large numbers of developing nations that wrestle with how to incorporate sustainability into their maritime logistics systems. The obstacles that developing countries encounter in their attempts to incorporate principles of sustainability include outdated infrastructure; inefficiencies due to lack of regulations; low levels of technology adoption; and operational bottlenecks that create low levels of productivity and efficiency within their seaports. It is observed that when a logistics system is inefficient, it often results in longer wait times for vessels and increased containers' dwell time (Kishore et al., 2024).

Basically, the Nigerian seaports are always having one type of operational challenge or another, including some combination of port congestion, lack of adequate cargo-handling equipment, poor hinterland connectivity to regional areas and lengthy bureaucratic cargo clearance

processes. All these operational challenges are associated with increased port congestion, long vessel waiting times, and increased delays in cargo movement through the overall supply chain due to the lack of an efficient port logistics system. The inefficiencies of a port logistics system may cause cargo to be diverted from Nigeria's ports to neighbouring countries that have more efficient port logistics systems, which adversely affects Nigeria's competitiveness in international maritime trade.

By implication, the adoption of sustainable logistics practices is an increasingly important strategy for improving port operation efficiency in Nigeria. Sustainable logistics initiatives can enhance seaport productivity and reduce their environmental impact. Hence, this study conducted a literature review to identify the prevalent themes in sustainable logistics studies and how these themes impact operational efficiency in the maritime sector.

2.0 LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Resource-Based View Theory

The study reviewed the Resource-Based View (RBV) theory propounded by Jay B Barney (1991). According to the theory, organisations can obtain sustainable competitive advantage through the acquisition, development, and effective utilisation of valuable, rare, hard to imitate and ultimately not replaceable (VRIN) resources. In concluding his work on the RBV of Firm Resource Competitiveness, Barney cited Birger Wernerfelt (1984) and stated that firms should be viewed as a bundle of resources and not as a collection of products. For this study, the RBV is relevant because it can demonstrate how sustainable logistics can enhance seaport operational efficiency through sustainable logistics practices (e.g., green technology, digital systems, automation, and advanced port infrastructure) that represent strategic internal resources. As strategic internal resources, these resources enable seaports operators to optimise the efficiency of their operational processes by reducing the time and cost associated with processing vessels, improving cargo handling and throughput. Therefore, the RBV provides a solid theoretical basis for linking the development of internal capabilities with the relationship between sustainable logistics and operational performance at seaports in terms of differences in operational performance across different seaports based on the availability of different resource endowments and levels of technology.

2.2 Conceptual Review

2.2.1 Sustainability Logistics

The concept of sustainable logistics in the maritime sector has progressively changed from predominantly environmental issues to a much broader analysis of environment, economy, technology and institutions integration. For example, the emphasis in earlier study was primarily upon the environmental aspect of sustainable logistics (Peris-Mora, Orejas, Subirats, Ibáñez & Alvarez, 2005). However, later studies added an additional emphasis on sustainable logistics used in green supply chains, energy efficiency and waste minimisation (Bouman, Lindstad, Riialand & Strømman, 2017; Davarzani Fahimnia, Bell & Sarkis, 2016). The most recent study describes sustainable logistics systems as being built around a strategic and systems-based approach, where various digital and operational technologies are used to help achieve both environmental performance and increased efficiencies of operation (Heilig, Lalla-

Ruiz & Voß, 2017; Tijan, Jović, Aksentijević & Pucihar, 2021). Furthermore, the growing use of smart ports and the types of digital technology/solutions are now actively reinforcing sustainable logistics to include Internet of Things (IoT), Big Data and artificial intelligence. These have been made available for real-time monitoring and optimising of all seaport operations (Jahangard, Xie & Feng, 2025; Li, Li, Zhang, Xiao & Sun, 2022). In addition, sustainable logistics systems have expanded beyond the boundary of the seaports they serve by also including the integration of port hinterland and intermodal transport systems. This helps to improve the flow of goods in and out of the port, while concurrently reducing congestion at the seaports (Abu-Aisha, Audy & Ouhimmou, 2024; Lam & Gu, 2013).

Sustainable logistics encompasses government regulations and collaboration among stakeholders along with the institutional frameworks that play a role in how shipping firms implement and maintain their sustainable practices (Cocuzza, Campisi, Ignaccolo & Twrdy, 2024; Osadume, Okene, Uzoma & Enaruna, 2024). In addition, the existing studies on sustainable logistics indicate that there will be short-term inefficiencies before the firms can gain long-term efficiency while implementing sustainable practices within their operations (Karagkouni & Boile, 2025; Santos, 2025). These studies support the assertion that sustainable logistics is an all-encompassing framework that integrates environmental leadership, technology-based solutions, systems integration, and closely aligned institutions to achieve improvements in seaport effectiveness (Kishore et al., 2024; Lim, Pettit, Abouarghoub & Beresford, 2019; Yen, Huang, Lai, Cho & Huang, 2023). Nonetheless, whether sustainable logistics will be effective is often determined by the context where it is developed, particularly in underdeveloped nations where shipping firms lack adequate infrastructure and other resources or capabilities to fully realise the benefits of sustainable logistics (Ashakah, Okeudo, & Onyema, 2025; Nwokedi, Nnaukwu, Nze & Emeghara, 2022).

2.2.2 Seaport Operational Efficiency

Seaport operational efficiency has been defined as the ability of a seaport to use all its various resources (infrastructure, labour, technology) to provide maximum throughput with the least amount of time spent on operations (turnaround time). As research advanced, early definitions were based primarily on productivity and technical efficiency, which were usually assessed via performance indicators and/or benchmarking against other seaports across the globe (Peris-Mora et al, 2005). More recently, Bouman et al. (2017); Davarzani et al. (2016) support the definition and asserted that efficient seaports incorporate sustainability issues into their operations and are more digitally advanced (Heilig et al., 2017; Li et al., 2022; Tijan et al., 2021). Hence, studies are beginning to reassess seaports' operational efficiency as an aspect of a broader logistics system. The efficient operations will depend on how well the seaport integrates with all parts of the hinterland transport network, as well as through multimodal connections (Abu-Aisha et al., 2024; Lam & Gu, 2013).

The seaport operational efficiency is often influenced by contextual variables such as infrastructure limitations, technological gaps, and weak institutional capacity. This can adversely affect optimal operational performance from being achieved in developing economies (Ashakah et al. 2025; Nwokedi et al. 2022). Seaport operational efficiency has been redefined as a multiple-dimensional, systems-based construct that integrates productivity, sustainability, digitalisation and institutional coordination in the maritime logistics ecosystem. Studies have shown that sustainable practices contribute to improving the efficiency of seaports by encouraging the optimal use of resources and their long-term competitiveness (Lim et al., 2019; Yen et al. 2023). However, Kishore et al. (2024) propose that sustainability is the main

part of current definitions of seaport operational efficiency. Coordination of seaport stakeholders through institutional/governance (policy) frameworks is also highly important with respect to improving the operational performance of seaports (Osadume et al., 2024; Cocuzza et al., 2024).

2.3 Empirical Review

The study on sustainable logistics and seaport operational performance has shown an increase in evidence of sustainability improving seaport performance. The relationship between sustainability practices and operational improvement is not always clear cut. Some studies revealed that sustainability has a negative effect on operational improvement while others find a positive relationship. In the majority studies have operationalized sustainability through efficiency measures such as turnaround time, throughput, berth productivity, and cost efficiency to determine the impact of sustainability on operational improvement. Empirical studies conducted by Lim et al. (2019) and Davarzani et al. (2016) provided evidence that using green logistics practices—such as energy efficient seaport equipment, reduced waste systems, and control of emissions—will lead to improvements in resource utilization and reductions in operational inefficiency. This evidence is confirmed in by Bouman et al. (2017), who found that decarbonising maritime transportation through alternative fuels and new technologies has a positive impact on both the environment and operational efficiency by reducing fuel consumption and providing a more stable operational process. Similarly, Zhang, Zeng, and Wang (2024) revealed that implementing carbon reduction measures and shore power systems decreased vessel idle time and optimizing energy use. Contrarily, Santos (2025) revealed that sustainability leads to increased long-term operational efficiency. However, in the short term, implementing sustainability initiatives typically result in sub-optimal operational performance due to the capital investment needed to implement and modify operations. This is further supported by Karagkouni and Boile (2025) who revealed that investment in green seaport structures and technologies will diminish operational efficiency at the initial stage. The seaports will need to transition through various stages of capital expenditure, staff recruitment/training, and reorganisation of processes.

Studies have provided empirical evidence on the positive impact of sustainable logistics (digitalisation) on operational efficiency (Heilig et al., 2017; Tijan et al., 2021). In particular, these studies have revealed how the implementation of "smart port" technologies (IoT devices, big data analytics, and integrated information systems) aid in decision making, reduce uncertainty, and improve cargo handling efficiency. Jahangard et al. (2025) support the finding and revealed that implementing artificial intelligence (AI) and machine learning (ML) applications also have a substantial favourable influence on berth allocations, vessel scheduling, and predictive maintenance. Li et al. (2022) similarly found that digitalisation improves the coordination of seaport stakeholders, thus enhancing overall seaport operational performance.

Nonetheless, digital technologies' accessibility and effectiveness differ in varying contexts, leading to contradictory finding in literature. Notteboom, Pallis, and Knatz (2025) contend that digitalisation increases efficiency at technologically sophisticated international seaports, but the study also state that similar efficiencies can't be achieved in developing areas because the existing infrastructure creates significant barriers to implementation (costs, lack of skilled professionals). Nwokedi et al. (2022) also found that inadequate digital infrastructure and weak institutional capacity negatively impact the ability to achieve operational efficiency. Given

these diverging findings, it is observed that the benefits of digitalisation are not experienced equally. They depend on region-specific technological readiness and institutional capacity.

The outcomes of empirical studies of integration between seaports and their hinterlands shed light upon the issue of how sustainable logistics influence operational efficiency through both supporting and contradicting findings. Lam and Gu (2013) showed that when an intermodal transport system is functioning at a higher level than a truck-only system, this helps reduce congestion and cargo dwell time and improve the efficiency of seaports. Abu-Aisha et al. (2024) also found that there is smooth flow of cargo when there is a connection between transportation systems used to move cargo between seaports and their hinterlands. This leads to improvements in logistics performance as measured by empirical criteria. Conversely, Ashakah et al. (2025) found that the poor quality of hinterland infrastructure in developing regions ultimately reduces the effectiveness of the various integration efforts being implemented. This affects operational efficiency in form of seaport congestion and cargo delays.

Automation and Smart Terminal operations is another key dimension of sustainability logistics explored by extant studies. AlKheder et al., (2022) demonstrated that automation in seaport operations improves coordination between logistics and seaport operations, lowers the amount of human error that occurs in logistics, and optimised efficiency of container handling. Tsagkaris and Moschovou (2025) lend credence to the finding and revealed that through automated systems, there is a significant increase in the amount of throughput and a decrease in turnaround times. These findings portend that automation plays an essential role as an enabler for achieving operational efficiency within sustainable logistics frameworks. Contrarily, Notteboom et al., (2025) revealed that automation creates numerous challenges such as high initial capital investment, increasing technological complexity, and displacing labour from existing jobs within the marine sector. These challenges may have the potential to offset the operational efficiency in seaports that do not have adequate access to either technical or financial resources.

Also, converging and diverging findings are shown in studies on green energy/decarbonisation, a dimension of sustainable logistics Parhamfar, Sadeghkhan, and Adeli (2023); Shen, Gao, Lu, Li, and Feng (2025) revealed that using renewable energy sources along with implementing carbon reduction measures can lead to increased operational efficiency because of reduced energy costs and more stable operations. Cocuzza et al. (2024) also found that seaports that incorporate sustainable energy systems and digital monitoring technologies achieve better coordination of seaport operations with less environmental impact than those that do not. Hence, these seaports are able to provide greater operational efficiency. However, Bouman et al. (2017) and Santos (2025) found that transitioning to green energy systems could possibly lead to disruption of operations (hence, increasing operating expense) resulting in lost productivity or a decrease in the overall ability to achieve efficiencies in an immediate timeframe. This portends that while there are long-term benefits associated with utilising green energy sources there may also be short-term disadvantages (in terms of efficiency) associated with making this transition.

A further inconsistency exists in the existing studies surrounding the differences in impacts of sustainable logistics on the developed and developing seaports. In developed countries' maritime sectors, empirical studies point towards a positive association between sustainable logistics practices and operational effectiveness. This is primarily attributed to the existence of advanced infrastructure, regulation, and technological capabilities within these economies as well as their relative robustness regarding structural supply chain issues (Osadume & et al.,

2024; Ashakah & et al., 2025). Conversely, when looking at regions where supply chain structures are not as robust due to poor infrastructure, governance, and limited technology access or proficiency, sustainable logistics practices tend to have much less impact. Following this observation, it can be concluded that there are significant geographical and institutional disparities in literature regarding the efficiency gains that can be expected from the implementation of sustainable logistics.

2.4 Conceptual Framework

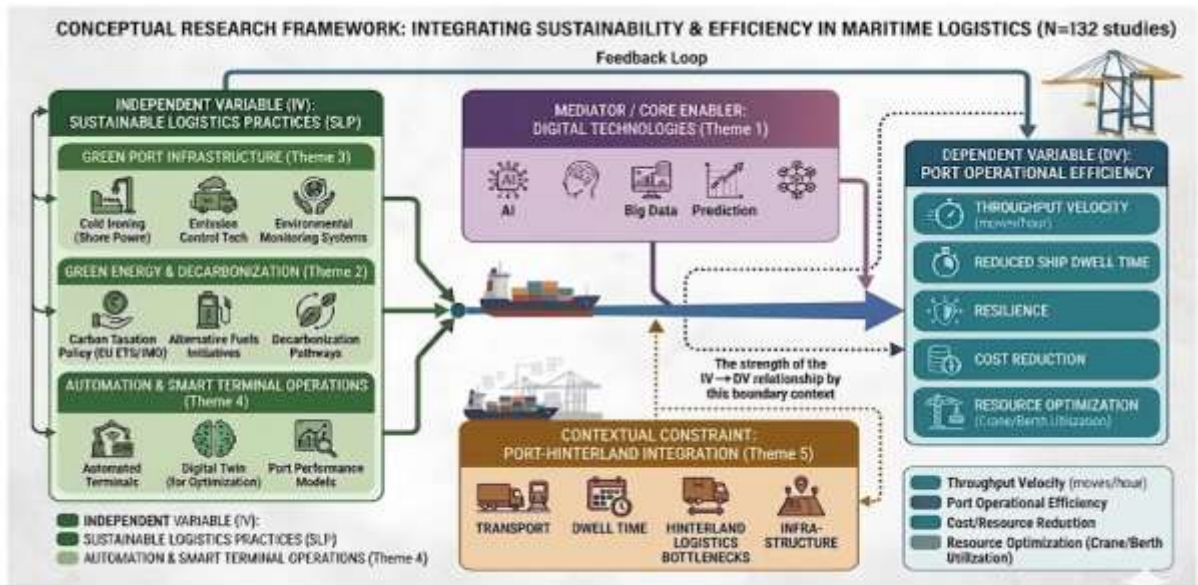


Figure 2.1: Conceptual Framework

Source: Researcher 2026

3. METHODOLOGY

The study employed a systematic literature review as the research design. The study followed 2020 PRISMA guidelines as a framework for conducting a systematic review. The study relies on a thematic analysis of 255 studies obtained. It analyses secondary data obtained through peer-reviewed literature, such as journal articles and conference proceedings, in Scopus, Web of Science, and IEEE. The literature identification, screening, eligibility, and inclusion processes completed through the PRISMA process provided a rigorous and replicable framework for selecting the studies to review. The PRISMA flow diagram is shown in figure 3.1

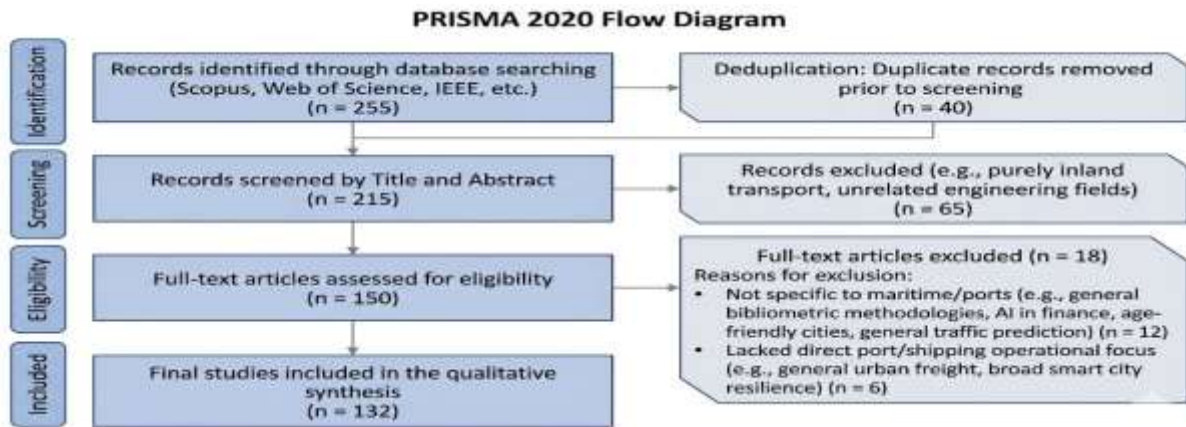


Figure 3.1: PRISMA Flow

A thematic analytic approach was used to analyze the 132 studies and subsequently identify key themes. These themes were verified using triangulation methods and thematic saturation which provided rigorous, reliable evidence. The thematic analysis provides an extensive and transparent synthesis of sustainable logistics practices in the maritime sector, while highlighting significant areas for further research.

4.0 ANALYSIS

This analysis systematically synthesizes the identified studies (132) based temporal evolution, disciplinary spread, geographic distribution, and thematic prevalence. Additionally, this section aims to provide a critical analysis of how the overall research focus of the maritime sector has evolved over the last two decades, in lieu of just providing a descriptive summary.

4.1 Temporal Evolution and Research Trends

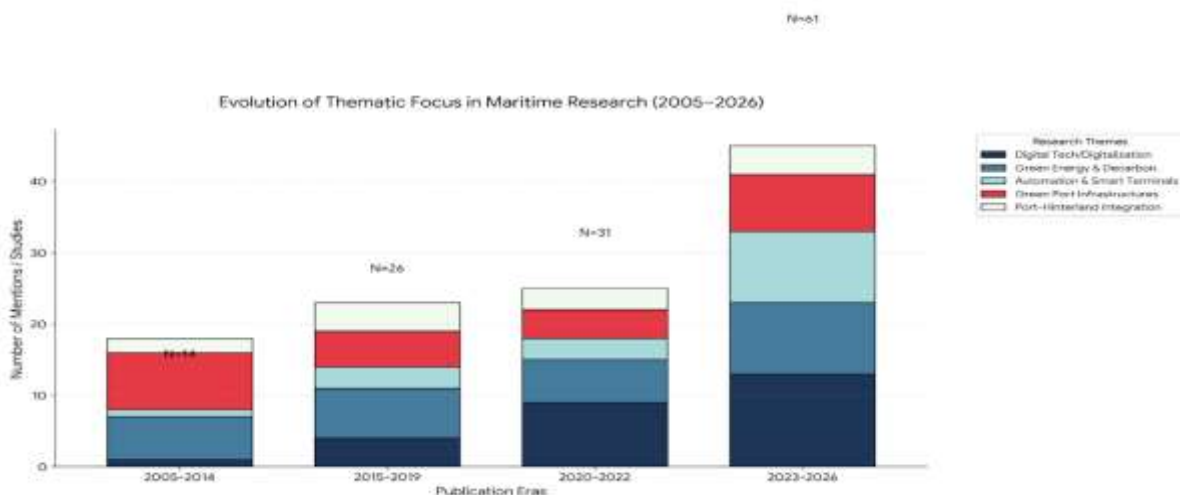


Figure 4.1; Evolution of Thematic Focus

Figure 4.1 revealed the transformation of maritime research priorities from a predominantly physical and construct-centered perspective to a unified digital/green system, which provides

a time-based thematic study. The transition from physical infrastructure to a full-fledged, interconnected integrated modern data-driven "Convergent Explosion" portends a significant evolution and development of sustainable logistics research.

From 2005 to 2014, studies focused on tangible infrastructure development, including both physical expansion and improvement of the environment at seaport. It is revealed that sustainability in this period was mainly approached through hardware-based solutions, including seaport facilities and energy-efficient installations. From 2015-2019, the focus of study shifted from tangible constructs toward conceptual and systemic view about seaport. Seaports began to be understood as systems with interconnections. Sustainability in this period was integrated into multiple forms of policy and energy management, and this integration was indicative of a movement toward more holistic governance of ports.

Due to widespread disruption caused by COVID-19 between 2020–2022, there was an extensive acceleration related to digital solutions. Data-centric approaches became the focus of research, as these approaches were viewed as critical means to enhance visibility, mitigate bottlenecks, and increase operational responsiveness within seaports through the application of digitalisation. The newest phase (2023–2026) is called convergence phase; it integrates three different areas: digitalization, automation, and sustainability. Additionally, the current literature in these areas discussed integrated solutions for automation using emerging digital technologies to achieve both decarbonisation and increased efficiency in operations. This is indicative of the creation of smart, autonomous, and environmentally sustainable seaport systems. Seaport logistics efficiencies have historically been studied in an ad hoc manner as an infrastructure improvement. Therefore, the research of sustainable seaport logistics has shifted from discrete infrastructure improvements to the creation of a fully integrated ecosystem.

4.2 Publication Patterns and Disciplinary Spread

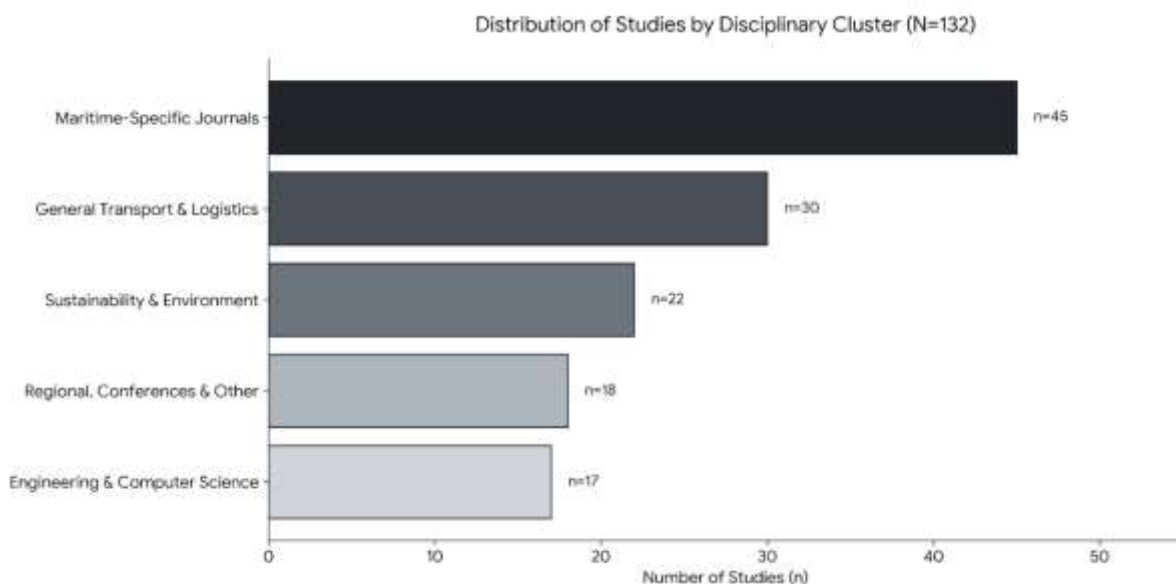


Figure 4.2: Distribution of Studies Disciplinary Cluster

Figure 4.2 provides a mapping of studies used for the analysis and demonstrate where most influential studies in smart and sustainable logistics are published. Mapping the disciplinary structure of the literature depicts a layered and interconnected research ecosystem, with smart and sustainable seaport logistics at the centre. Maritime-related journals dominate the field, suggesting that smart and sustainable seaport research has developed into an independent academic sub-discipline that focuses on operational issues specific to the field. The transport and logistics disciplines provide the bridge to the core by placing seaports within a global supply chain, emphasising their roles in the economic system, and policy modelling. Much of the research conducted is at the multidisciplinary frontier, integrating both sustainability/environmental science disciplines and engineering/computer science disciplines. This integrative element showcases the technical and environmental interconnectedness of the two fields. Conference proceedings and regional studies comprise the long tail of the research, often containing emerging innovations and findings about experimental research that reflect the most current trends. Overall synthesis of the discipline aggregates it as a core–bridge–frontier–emerging model in which maritime journals serve as the anchors of the discipline. Logistics journals connect the discipline to greater systems. Sustainability and engineering promote innovation, and grey literature documents the most recent advancements.

4.3 Geographic Distribution and Contextual Differences

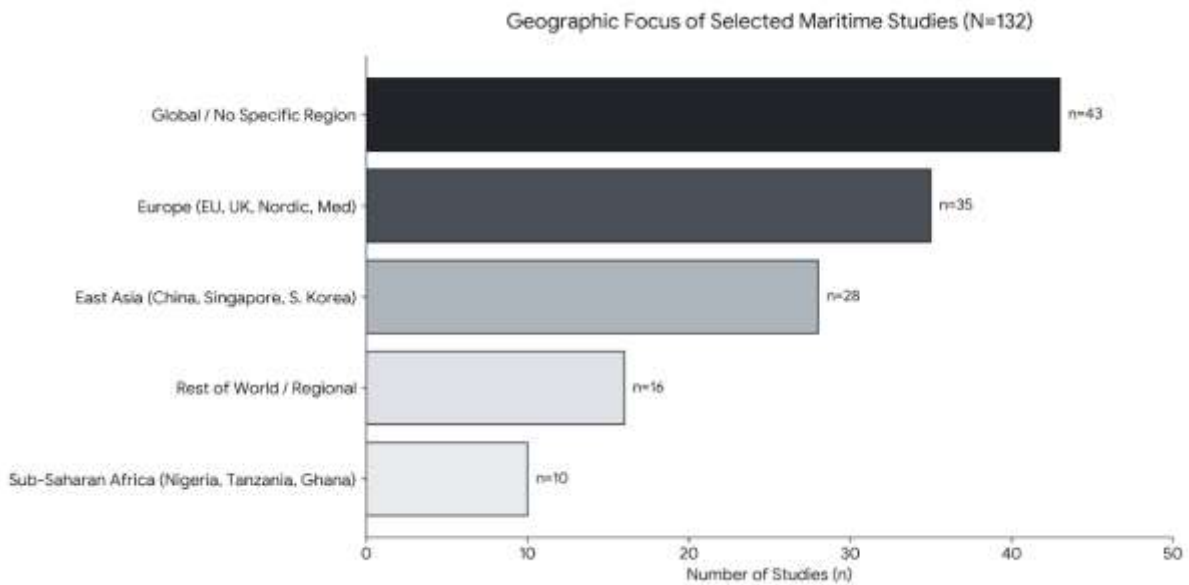


Figure 4.3: Geographic Distribution of Studies

With regards to the geographic dispersion of the reviewed studies, it shows the presence of highly uneven but globally distributed research landscapes in smart and green port logistics. There are a significant number of studies that take on a theoretical or global perspective. This demonstrates that there continues to be effort put towards constructing universal models and frameworks with applications globally. As revealed in the study, Europe is the largest regional representation of the studies of green port research, driven primarily by a strict regulatory framework for environmentally based requirements and the presence of sustainable governmental policies. Comparatively, it is revealed that the East Asia has the largest regional representation of studies of smart port research and automation.

The studies emphasised more on technology advances, high throughput efficiency and intelligent terminal operations. However, Sub-Saharan Africa has a very small presence but increasingly visible in green port research. It is revealed that the majority of studies are directed at the infrastructural barriers to effective seaport operation, comparative ineffectiveness of seaport operations, and opportunities for technology leapfrogging. It is observed that the global research environment has been determined to be comprised of a tripartite structure which is defined by theoretical development, sustainability leadership, and technological innovation. These global areas of research can be differentiated by region while the developing regions represent critical areas for future research and development efforts.

Table 4.1: Regional Specialization in Maritime Research.

Region	Research Character	Competitive Advantage
East Asia	Technocentric	Lead in AI-driven terminal efficiency.
Europe	Regulocentric	Lead in sustainable policy and infrastructure.
Sub-Saharan Africa	Logistics-centric	Focus on efficiency and hinterland bottlenecks.
Global	Theoreticocentric	Provides universal frameworks and trend analysis.

Source: Researcher, 2026

Table 4.1 above revealed that there is a distinct regional specialisation in maritime research priorities. East Asia has been determined to be the centre of technology, emphasising the use of artificial intelligence and big data to optimise high-volume seaport operations. It is revealed that Europe will be the main centre of policy and green innovation at the present time. This is mainly due to strict environmental regulation in Europe and their focus on decarbonisation and green port infrastructure. Sub-Saharan Africa will be the logistics frontier. This means that most of the research focus on improving the functioning of basic seaports, eliminating bottleneck and improving the connectivity of the hinterland. Finally, both global studies and reviews provided an overall framework to identify key trends such as digitalisation and sustainability, which will provide guidance for researchers in all regions. The findings demonstrate a globally networked yet regionally distinctive research environment. Therefore, each region contributes to the maritime research agenda in their own way based on their technological capacity and regulatory frameworks, as well as their level of development.

4.4 Thematic Prevalence in sustainability logistics Research

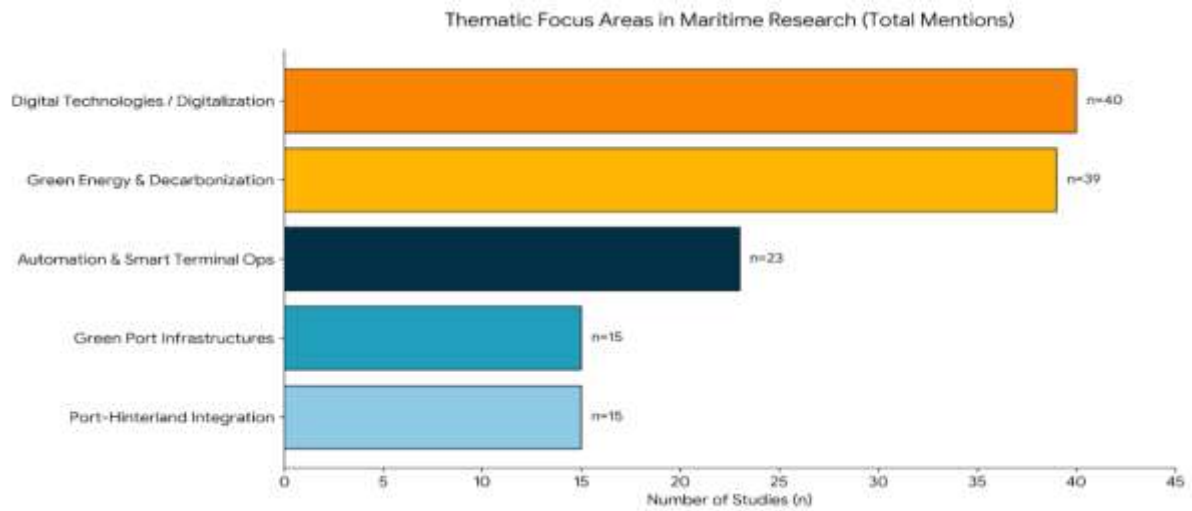


Figure 4.4 Thematic Prevalence

Theme 1: Digital Technologies / Digitalization

As shown in Figure 4.4, digitalisation is revealed to be the most current dominant developed theme across studies. The theme encompasses machine learning, AI, AIS data analytics, and digital transformation in the maritime sector. Heilig et al. (2017) and Tijan et al. (2021) found that digitalisation key enabler for smart seaport systems. Xiao et al. (2022); Chen et al., (2024) also found that the use of advanced AI technologies related to trajectory prediction and decision-making. The review discovered that many studies within digital technologies/digitalisation remain algorithm-based or simulation-based rather than being derived from actual field tests with respect to operational and sustainable outcomes. While several blockchain studies (Queiroz, Telles & Bonilla, 2020; Zhou, Soh, Loh & Yuen, 2020) demonstrate conceptual potential for use within the maritime sector, large-scale implementation is still lacking. In summary, this theme comprises of a large degree of technological advancement but lacks sufficient empirical evidence as well as associated integration within the larger seaport ecosystem.

Theme 2: Green Energy & Decarbonization

This study uncovered green energy/decarbonisation is a policy-driven tool of reducing maritime transportation emissions and the pressure on all countries globally to reduce such emissions. Carbon taxation schemes and alternative fuel initiatives provide important inputs to reduce emissions in the maritime sector. Foundational studies by Bouman et al. (2017); Psaraftis and Kontovas (2010); focus on the macroeconomic decarbonisation pathways that might exist. However, more recent works by Shen et al. (2025) and Zhang et al. (2024) deal with carbon neutrality and sustainability transitions. Although several studies on alternative fuels exist (Alamouh, Ölçer & Ballini, 2022; Parhamfar et al., 2023). The majority of these studies focus on technological solutions at the macroeconomic and policy level and do not address issues concerning how to implement new technologies, how much alternative fuel will cost, and whether alternative fuel solutions will be feasible in particular regions. The study

observed that green energy/decarbonisation is strong in terms of concepts and regulations. However, it is not strongly rooted in terms of operational realities in developing countries.

Theme 3: Green Port Infrastructures

The study also uncovered Green Port Infrastructures is theme prevalent in sustainable logistics studies. The study observed that this theme focuses on providing localised solutions using physical infrastructures, which includes shore power, emission control technologies, and environmental monitoring systems. Daniel, Trovao, and Williams (2022); Wu and Wang (2020); Yu, Voß, and Tang (2019) identified the use of cold ironing as one way to reduce emissions while ships are at berth. However, the study revealed that previous studies by Peris-Mora et al. (2005); Puig, Wooldridge, and Darbra (2014) provide primary indicators for the development of seaport sustainability from an environmental perspective. Overall, research relating to this theme is limited, fragmented, and heavily reliant on technologies with few integrated systems reflected in this study. It also appears that more recent studies have very little to no conceptual advancement. This indicates little to no development in methodological innovation connected to the green infrastructure theme.

Theme 4: Automation & Smart Terminal Operations

Furthermore, the study uncovered Automation and Smart Terminal Operations prevalent in sustainable logistics. This theme includes automated terminals and the development of digital twins, as well as optimization models for improving seaport performance. Recent studies by Notteboom et al. (2025) and Pham (2023) uncovered the development of smart seaport architectures. Also, Li, Jiao, and Yang (2023); Wang and Meng (2017) revealed the role of big data and analytics in enhancing crane operations and operational efficiency. Given the advancements in technology, the majority of the studies conducted to date are based solely on simulations with the emphasis placed on advanced seaports. Furthermore, there has been little consideration for the effect of automation on the seaport workforce and the challenges of implementing automation in less developed seaports. In addition, the focus on increasing efficiency in seaports has limited the understanding of automation in terms of its impacts on society and the institution of seaports as a whole.

Theme 5: Port-Hinterland Integration

The study also uncovered Port-Hinterland Integration, being one of the relevant themes in sustainable logistics studies. It is observed that the theme centered on intermodal transportation and issues related to dwelling time, and the presence of bottlenecks in logistics. The study includes foundational studies conducted by Lam and Gu (2013) and Lindholm and von Wieding (2012) that expound upon the significance of the integration of seaports and cities. Subsequently, Mbachu, Ndikom, Nze, and Nwokedi (2025); Nwokedi, Nwachukwu, Eru, and Ogwo (2022) demonstrate that inefficiencies such as the use of outdated infrastructures are present in developing regions and create obstacles to achieving effective and efficient logistics performance. This theme is limited in its relevance to the real-world logistics performance in relation to other themes. It has typically been used to support the descriptive nature of research literature rather than providing solutions to alleviate congestion or increase intermodal connectivity. In addition, there is currently limited use of digital technology to support logistics functions serving the hinterland. This represent a substantial gap in research related to the

application of smart technologies for improving intermodal connectivity and alleviating congestion.

4.5 Discussion of Findings

The study revealed that studies between 2005 and 2023, have fundamentally shifted. It has gone from being fragmented and focused on infrastructure to being a multi-dimensional, integrated area of research. The evolution seen in sustainable logistics studies has not only taken place historically but also across multiple disciplines, geographical regions, and research themes.

Historically, there has been a transition in research from an infrastructure-based paradigm to one that is predominantly digital/green by 2023-2026 due to increased complexity of seaport systems. In the past, research on seaports was based on traditional seaport development models, which relied heavily upon physical infrastructure. However, the digital/automated evolution reflects that efficiency in seaport operations is no longer bounded by just physical infrastructure but also by access to real-time data, integration of systems, and response times. Furthermore, the period of accelerating activity between 2020-2022 indicates that the major global disruptions experienced around the globe acted as a catalyst for innovation in terms of how seaports develop data-driven resilience measures. Sadly, while the convergence phase of sustainable logistics outlines a need for integrated sustainable transportation solutions, the literature continues to provide little evidence of how these integrated solutions actually perform relative to their counterparts in emerging economies.

The study revealed that sustainable maritime logistics are geographically and not universally dependant on context. Europe maintains its predominant position in green research due to regulatory pressures. East Asia has a strong position in smart technologies because of high volumes of operations and technological capabilities. Finally, Sub-Saharan Africa's focus on basic logistics efficiency is indicative of a gap between developed and developing countries. Fundamental issues, such as inadequate infrastructure and/or inadequate hinterland connections take priority over advanced digital or decarbonisation solutions. This geographic disparity suggests an important limitation of the literature based on smart and green solutions. The study shows that many proposed solutions cannot be transferred across regions, particularly to emerging economies. Therefore, without contextual adaptation, the global applicability of today's sustainable models remains questionable.

The results from the thematic analysis also show there is an imbalance between the technological advances and how these can be practically applied. As revealed in the study, digitalisation is presented as the main theme in that it represents an ongoing process of development in the fields of artificial intelligence, machine learning, and data analytics. It is apparent that digital solutions primarily rely on simulation rather than real-world validation. It thus implies that there is a lack of alignment between the innovation of digital technologies and how they are implemented in operations. The study also revealed that research on decarbonisation is well developed in terms of policies and strategies. However, there is a lack of attention given to the cost, feasibility and barriers to implementing decarbonisation strategies, especially in resource-constrained environments. The study further revealed that there is a large body of research related to Green Port Infrastructure. However, it appears to be narrowly focused and stagnant when compared to the need for a more integrated and system-based approach to seaport infrastructure solutions.

Similarly, the study revealed that automation and smart terminal operations represent the potential for operational efficiency through digital technologies. It is revealed that much of the empirical evidence are based on advanced seaports which tend to emphasise the value and benefits of digital technologies. However, these studies do not sufficiently consider social, institutional and labour force implications of the increased use of digital technologies. Thus, there is an optimistic perspective towards digital technologies that may not likely reflect the complexity of the real-world implementation of digital technologies. Additionally, the study revealed that the integration of seaports with their hinterlands, which is thought to be one of the key influencers of logistics efficiency, remains under-developed and largely descriptive. Thus, the integration of digital solutions into hinterland systems remains a significant gap in literature, especially when considering that in many regions. Seaport inefficiencies are more often driven by constraints associated with landside operations than constraints associated with port-side operations.

5. CONCLUSIONS AND RECOMMENDATIONS

The study concludes that sustainable logistics has developed into an integrated progressive and multi-disciplinary field. The traditional infrastructure-based perspective has changed to an integrated converged system driven primarily by digitalisation and automation with a focus on decarbonisation. The study concludes that significant progress has been made in technological innovation and policy actions. However, there are still many areas of the world that remain underdeveloped in terms of technological and policy advancements related to logistics, especially considering the number of regions and themes in which development has occurred. Research and development on smart and green port strategies has primarily taken place in advanced economies, while developing economies continue to struggle with logistical and infrastructure development challenges. In addition to this disparity between developed and developing countries, there exists an ongoing gap in the literature between theoretical advancement and actual on-the-ground application of logistical solutions. A significant number of studies are either simulation-based, policy-driven, or technologically optimistic and not adequately supported by empirical evidence. Hence it is concluded that achieving sustainable and efficient seaport operations will require more than technological advancements/ It will require the need for a systems-based, holistic approach that takes into account geographic, logistical, and governance concerns. The study recommends that all stakeholders in the maritime sector must adopt holistic frameworks that include digitalisation, green energy, automation, and hinterland connectivity. Furthermore, all seaports must invest in human resources development to effectively adopt the technologies that are associated with AI, big data analytics, and smart logistics systems. The study also recommends that inter-agency collaboration between governmental entities, private operators, and technology providers should occur so that investment in smart and green port facilities can be supported.

5.1 Practical Implications

Give the outcomes of the study, efficient seaport operations require a balanced and context-based approach that integrates sustainable logistics practices. Seaport authorities can use smart technologies while also developing their green infrastructure and improving operational efficiencies. Practitioners should prioritise integrating data, enhancing visibility, and creating collaborative digital platforms to achieve higher efficiency levels. For developing economies, addressing the key fundamentals (port congestion, long dwell times, poor hinterland

connectivity), should be the primary goal prior to implementing smart technology in their port development strategies.

5.2 Gaps in Literature

One significant gap in the study is the lack of empirical validation. Many studies use simulated or theoretical models rather than real world research or longitudinal data for empirical evidence. Thus, validation takes place through analysis of theoretical data alone. In addition, little emphasis has been placed on developing countries especially, in Africa where contextual issues are underexplored. The literature reviewed demonstrates that key themes lack proper integration. Digitalisation, sustainability and automation have all been considered separate issues rather than interrelated systems. Important social and institutional factors (workforce impact/guidance constraints) lack adequate consideration in the discussions found in the literature reviewed. There is also a low number of studies which have explored port-hinterland integration and applied advanced digital solutions to landside logistics. Implementation issues such as financial requirements, cost, and scalability are also typically ignored by researchers; these limitations indicate that the theoretical innovations proposed have not translated into real world implementation.

5.3 Areas for Further Studies

Future studies on smart and green seaport initiatives should focus on providing empirical and longitudinal studies as these provide examples of how these initiatives actually work. Future research needs to address developing countries such as Sub-Saharan Africa so that they can demonstrate how they can develop context-specific, scalable solutions. The studies also need to combine digital technology with hinterland transportation systems and discuss how these technologies could improve the efficiency of intermodal transportation. More attention is required for the socio-technical aspects of smart and green ports, including governance issues relating to institutional frameworks, workforce development, and economic viability. The studies should consider the implementation of decarbonisation policies when conducting cost-benefit analyses for the use of sustainable technologies. Finally, the studies should conduct comparative regional analyses to identify best practices to help in implementing smart and green seaports across different global contexts.

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