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Port Sustainability Framework in Thailand: ESG Indicators Approach

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ABSTRACT

ESG (Environment, Society, Governance) management is being applied in the world's industries, including ports, to enhance sustainable development. For the port sector, the world's ports have increasingly adopted policies to drive ESG projects in alignment with sustainable port development goals. This research aims to identify port sustainability indicators and analyze the interrelationship among ESG dimensions related to the port environment, port society, and port governance. Qualitative and quantitative methods are employed to identify port management indicators that affect the operation of cargo ports, utilizing a systematic document analysis tool. A wide range of academic and institutional sources was reviewed to ensure the comprehensive identification of relevant indicators. The finding indicates that twenty-nine port sustainability indicators affect port sustainability management, including the nine indicators of environmental port, the nine indicators of social port, and the eleven indicators of governance port. These critical indicators reflect both global best practices and context-specific needs, and they play a central role in managing the port's sustainability and guiding control strategies for improving competitiveness and compliance with international standards. Based on these findings, a port sustainability framework was developed as a practical operational tool to evaluate port performance, guide decision-making, and align port operations with Thailand's national policies and global sustainability standards. This framework also provides a foundation for future empirical validation and offers practical implications for policymakers and port stakeholders.

Keywords: Port Sustainability; Port Environment; Port Society; Port Governance; ESG Factors

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1. Introduction

Maritime transport plays a crucial role in the global supply chain and is often considered the backbone of international trade and global logistics. Around 80% of global goods trade by volume is carried by sea, underscoring the enduring importance of maritime transport throughout history and into the present day. This sector is expected to continue growing in the years ahead ^[1,2]. Since the early 1990s, global seaborne trade has shown a steady upward trend. Between 1990 and 2021, the volume of goods transported by sea was more than doubled—from approximately 4 billion to nearly 11 billion metric tons. In response to this growth, the global merchant fleet has also expanded significantly to accommodate the increasing demand for maritime transport ^[3].

Ports represent a key component of infrastructure that enables the continuity of maritime transport operations. They serve as key nodes where cargo transfers between land and sea, either being loaded onto ships or unloaded for inland distribution. Beyond their role in facilitating cargo movement, ports are also the sites of essential logistical activities, such as storage, handling, and transshipment of goods ^[4,5].

The Thai government has recognized the strategic importance of port development as a key driver for enhancing the country's competitiveness on the global stage. As part of Thailand's 20-Year National Strategy (2018–2037), port development has been recognized as a critical priority. The government aims to promote the transformation of traditional ports into sustainable ports—facilities that not only respond efficiently to user demands but also operate in a manner that aligns with the United Nations' Sustainable Development Goals (SDGs). This includes balancing environmental responsibility, economic viability, and good governance.

The concept of a sustainable port reflects a shift in how port operations are viewed—not merely as centres of commerce but as agents of sustainable development. Sustainable ports integrate economic efficiency, environmental stewardship, and social responsibility into their core functions. This includes minimizing

Greenhouse gases (GHG) emissions, utilizing clean technologies such as shore power and energy management systems, promoting decent work, and engaging with surrounding port communities in decision-making ^[6–8]. Furthermore, sustainable ports contribute directly to many SDGs, including SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 8 (Decent Work and Economic Growth), and SDG 11 (Sustainable Cities and Communities).

A practical framework for implementing sustainability in port operations is the Environmental, Social, and Governance (ESG) concept, which encompasses the Environmental, Social, and Governance dimensions, offering a holistic approach that enables port and terminal operators to operate more efficiently and responsibly. On the environmental dimension, it emphasizes minimizing environmental impact through actions such as reducing GHG emissions, managing waste, and conserving energy. The social dimension focuses on ensuring worker safety, promoting community engagement, and distributing benefits equitably. Additionally, the governance dimension emphasizes transparency, accountability, and ethical management practices ^[9]. This framework has been widely adopted across both the public and private sectors worldwide, including in ports. Moreover, the world's top-tier ports have already integrated ESG principles into their operations and management ^[10].

In Thailand, the Port Authority of Thailand has recently introduced the ESG concept for port development in early 2024. However, the initiative remains in its early stages of ESG adoption. Currently, many port and terminal operators lack standardized ESG indicators for managing port operations within the ESG framework. Moreover, there is remaining uncertainty among terminal operators regarding whether ESG implementation can support and promote sustainable port development. This lack of standardized ESG indicators and the absence of a validated operational framework have created a gap between policy aspirations and implementation capabilities. Without a clear, evidence-based model tailored to the Thai context, port authorities and operators may struggle to adopt ESG principles effectively.

This study systematically identifies ESG indicators through a comprehensive review of academic literature and national sources related to Thai ports, using a document analysis approach. It also explores how the ESG dimensions interact, rather than treating them in isolation as seen in much prior research. Theoretically, this study contributes a structured ESG indicator framework tailored to the port sector, with particular emphasis on the interdependencies among ESG dimensions—an area often overlooked. Practically, it offers a context-specific model that port authorities and policymakers in emerging economies can use to assess, monitor, and enhance sustainability performance. By addressing the lack of integrated, locally relevant ESG frameworks—especially in Southeast Asia—this study adds meaningful value to both academic discourse and real-world port sustainability practices.

The objective of this study is to develop a context-specific ESG indicator framework for Thai ports by systematically identifying relevant indicators and examining the interrelationships among the ESG dimensions. This will help to fill the gap between sustainability policy goals and operational aspects within the Thai port context.

2. Materials and Methods

This study employed a document analysis approach to identify key ESG indicators and examine the interrelationships among the ESG dimensions within the context of Thai ports. Firstly, it focuses on identifying key ESG indicators and analyzing the relationships among these three dimensions in the context of Thai ports. The study employed document analysis as a primary research method based on a comprehensive review of related literature and reports. Data were gathered from seven academic databases—Emerald, Web of Science, SpringerLink, ScienceDirect, IEEE, Google Scholar, and Semantic Scholar—covering publications from 2015 to 2025. The search was conducted using keywords such as “Environment management indicator/ Key performance indicator (KPI) in port,” “Social management indicator/KPI in port,” “Governance management indicator/KPI in port,” “Sustainable management indicator/

KPI in port,” and “ESG management indicator/KPI in port.” To ensure relevance and analytical rigour, specific inclusion criteria were applied. Articles were selected if they (1) focused on sustainable port operations or management, (2) addressed at least one ESG dimension, and (3) offered conceptual insights or empirical findings relevant to sustainability in port contexts.

In addition to academic literature, the study also reviewed news articles, annual reports from the Port Authority of Thailand and the Marine Department, and port-related reports from international organizations such as United Nations Conference on Trade and Development (UNCTAD) and Economic And Social Commission For Asia And The Pacific (ESCAP.) To ensure the validity of the ESG indicators synthesized from the document review, NVivo software was used to code the dataset using pre-defined keywords systematically. The frequency and consistency of coded references served as a practical basis for validating the applicability and relevance of each indicator. Based on the gathered information, ESG indicators were identified, and the relationships between the environmental, social, and governance dimensions were explored. Finally, the results were examined through thematic synthesis, and a framework construction methodology^[11,12] was applied to develop a framework for port sustainability in the Thai context. **Figure 1** presents the research framework, clarifying the overall research process and providing a clearer understanding of the study’s methodological approach.

Document analysis encompasses both qualitative interpretations and quantitative descriptions of texts, serving as a primary method that involves systematically reviewing and interpreting various types of documents to extract facts, patterns, and relevant information^[13,14]. This method is especially valuable when studying complex frameworks, such as ESG, in the context of sustainable port management, where diverse sources—academic, technical, and institutional—must be integrated. In this study, document analysis serves as the primary methodology for identifying ESG indicators relevant to ports in Thailand. The process enables authors to examine how ESG dimensions have been defined, measured, and implemented across glob-

al and local port systems. Unlike surveys or interviews, document analysis provides access to retrospective and pre-existing data, making it a cost-effective and efficient strategy for program evaluation and policy development^[15,16]. By applying document analysis, this study not only identifies key ESG management indicators for port operations in Thailand but also examines how the E, S, and G dimensions interact to support a more sustainable, accountable, and effective port management framework. In this context, document analysis is a re-

source-efficient method well-suited for developing conceptual frameworks, especially in emerging research areas. It identifies recurring patterns, policy trends, and theoretical insights across diverse academic and institutional sources without the cost of fieldwork. Although it does not capture real-time input from industry stakeholders or rapidly changing conditions, this reflects the method's scope rather than a flaw. As a foundation, document analysis offers structured evidence for future empirical research.

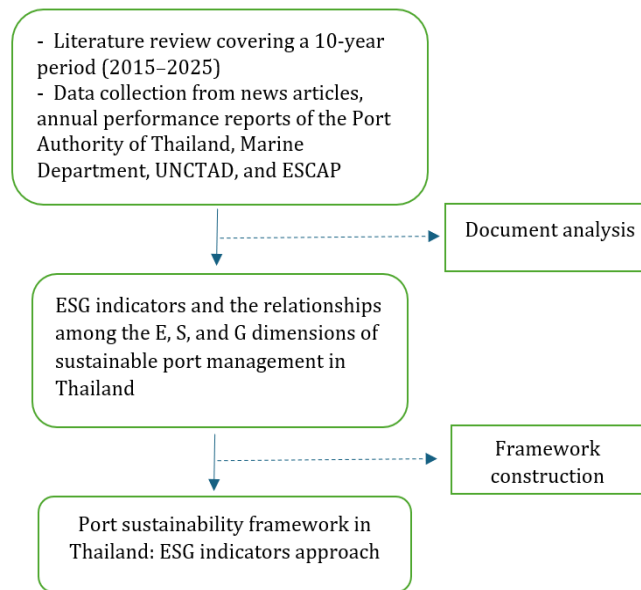


Figure 1. The framework of the research approach.

3. Results

The results of this study are divided into two parts. The first part is the result of the document analysis of ESG indicators. The second part is the port sustainability framework in Thailand.

3.1. ESG Indicators

3.1.1. Literature Review on ESG Management in Port

ESG stands for Environmental, Social, and Governance, which refers to how responsibly and sustainably an organization operates across these three dimensions. The Environmental dimension focuses on reducing environmental impacts, such as carbon

emissions, managing waste effectively, and promoting energy efficiency. The Social dimension highlights how port and terminal operators treat their employees and engage with communities, emphasizing labour rights, workplace safety, and social inclusion. The Governance dimension centres on ethical leadership, transparency, and accountability in decision-making. Over the past decade, ESG has evolved from a reporting tool to a core strategy for long-term value creation. Both investors and regulators increasingly use ESG criteria to evaluate enterprise risk and resilience in an uncertain global economy. In response, stock exchanges and organizations worldwide, including the World Federation of Exchanges (WFE), have developed standardized ESG reporting metrics to guide companies in disclosing relevant and meaningful information^[17].

This study applied document analysis as the pri-

primary research method to identify ESG indicators relevant to sustainable port management in Thailand. The literature review process involved retrieving academic and institutional publications from seven databases—Emerald, Web of Science, Springer Link, ScienceDirect, IEEE, Google Scholar, and Semantic Scholar—covering the years 2015 to 2025. A total of 115 documents were selected based on relevance to port sustainability, ESG practices, and port governance in both global and regional contexts. Selection criteria included the presence of ESG-related terminology or frameworks and the inclusion of port-specific operational or strategic con-

tent. The database search used the following keywords: “Environment management indicator/KPI in port,” “Social management indicator/KPI in port,” “Governance management indicator/KPI in port,” “Sustainable management indicator/KPI in port,” and “ESG management indicator/KPI in port.”

Figure 2 shows the distribution of studies based on keyword analysis. Among the 115 articles, 50 focused on environmental indicators, followed by 12 on governance, 12 on sustainable management, 7 on social indicators, and 6 on ESG indicators. This count is based on keyword analysis from the literature review.

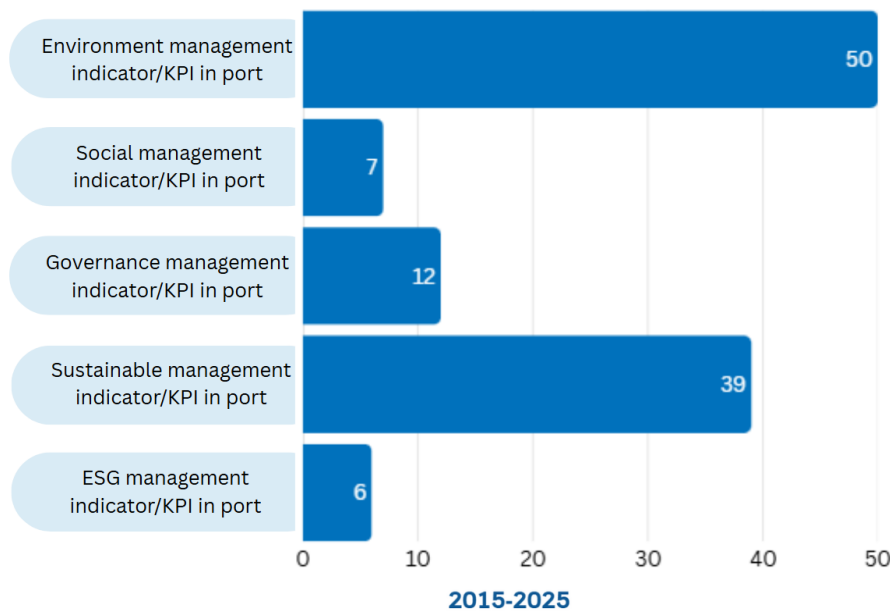


Figure 2. The results of the document search.

In addition to the academic sources mentioned above, the study also examined literature, including news articles, annual reports from the Port Authority of Thailand and the Marine Department, as well as port-related reports from international organizations such as UNCTAD and ESCAP. Based on these sources, the study identified and proposed ESG management indicators for the Thai port context, encompassing environmental, social, and governance dimensions.

Recent academic literature has shown a growing interest in integrating ESG dimensions into port sustainability evaluation. Several key studies are summarized below. These works vary in their research focus—from proposing ESG scoring models^[18] to em-

pirical assessments of ESG implementation in national port systems and to identifying barriers to ESG-aligned investments^[19]. Additionally, some studies revisit traditional KPIs to reflect the evolving expectations of sustainable ports^[20].

While these studies offer valuable insights, several critical gaps remain. First, most existing research focuses on ports in developed regions or large emerging economies, such as China and Brazil, with limited contextualization in Southeast Asia, particularly in Thailand. Second, although the importance of ESG indicators is widely acknowledged, there is a lack of consensus or a standardized set of ESG indicators tailored specifically for port operations in the Thai context. Third, and

perhaps most importantly, prior studies treat E, S, and G dimensions independently without investigating the interrelationships among these components. Understanding how ESG factors interact can provide a more integrated and strategic perspective on sustainable port development.

Therefore, this study will address these gaps by proposing a contextualized ESG indicator framework for Thai ports and examining the relationships among E, S, and G dimensions. Such an approach not only contributes to academic literature but also provides practical implications for policymakers and port and terminal operators in designing ESG-aligned sustainability strategies.

3.1.2. Identify ESG Indicators

To identify suitable ESG indicators for port manage-

ment practice, this study employed an extensive document analysis to identify key ESG indicators relevant to the Thai port context. The analysis encompassed academic publications from seven international databases, including institutional reports and literature, over the past 10-year period, with a focus on both global practices and Thai-specific contexts. The objective was to extract measurable, practical, and policy-relevant ESG indicators that reflect sustainability performance for port operations.

Table 1 presents a synthesis of the 29 ESG indicators, categorized into three main port management dimensions: Environmental (E), Social (S), and Governance (G). Each indicator is accompanied by examples of measurement variables and key references, providing a foundation for applying ESG management practice in port operations.

Table 1. ESG indicators and examples of measurement variables.

Indicator	ID	Example of Measurement Variable	Reference
Environmental in port management dimensions			
GHG Emissions reduction from port operation	ENV1	1. Total amount, in CO ₂ equivalents 2. Total amount of GHG emissions	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Gacek et al. ^[21] , Schipper et al. ^[22] , Wang et al. ^[23] , Kaup et al. ^[24] , Muangpan and Suthiwartnarueput ^[25] , Gianoli and Bravo ^[26] , Lin et al. ^[27] , Khorram ^[28] , Kadir et al ^[29] , Ehlers et al. ^[30] , UNESCAP ^[31] , UNCTAD ^[32]
Air Quality Control in Port Areas	ENV2	1. PM2.5 concentration in the port area 2. Number of days exceeding air quality standards 3. SOx emissions from port operations	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Muangpan and Suthiwartnarueput ^[25]
Oil spill from port operations	ENV3	1. Number of oil spill incidents 2. Total volume of oil spills	Gu et al. ^[10] , Wang et al. ^[23] , Kaup et al. ^[24] , Khorram ^[28] , Pallis et al. ^[33] , Budiyo and Fernanda ^[34] , Kwesi-Buor et al. ^[35]
Noise Pollution from Port Activities	ENV4	1. Average noise level from port activities 2. Number of community complaints regarding noise 3. Percentage of Noise monitoring coverage	Gu et al. ^[10] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25] , Schenone et al. ^[36] , Pandey ^[37] , Di Vaio et al. ^[38]

Table 1. Cont.

Indicator	ID	Example of Measurement Variable	Reference
Energy Conservation Capability in Port Operation	ENV5	1. Throughput energy consumption 2. Energy-saving rate 3. Total amount of energy directly consumed 4. Total amount of energy indirectly consumed	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25] , Di Vaio et al. ^[38]
Waste Management from Port Operation	ENV6	1. Total waste generated from port operations 2. Incidents of illegal waste discharge to sea 3. Number of waste collection points within the port	Gu et al. ^[10] , Dos and Pereira ^[18] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25] , Di Vaio et al. ^[38]
Port Operation Resource Efficiency	ENV7	1. Water consumption/Water recycle 2. Waste recycling rate 3. Renewable Energy Utilization Rate	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25] , Di Vaio et al. ^[38]
Climate Risk Mitigation for Port Operations	ENV8	1. Total amount invested in climate-related infrastructure/ resilience. 2. Existence of Climate Risk Assessment Plan	World Federation of Exchanges ^[17] , Gacek el al. ^[21] , Schipper et al. ^[22] , Wang et al. ^[23] , Kaup et al. ^[24] , Kadir et al. ^[29] , UNCTAD ^[32] , Budiyo and Fernanda ^[34] , Kwesi-Buor el al. ^[35] , Di Vaio et al. ^[38] , UNCTAD ^[39] , Bagus and Hanaoka ^[40] , Dias et al. ^[41] , Hänsel et al. ^[42]
Environmental Management in Port Operation	ENV9	1. Existence of a formal Environmental Policy 2. Existence of Environmental Management System Certification (ISO 14001) 3. Monitoring and Reporting of Key Environmental Indicators 4. Environmental capital investment	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25] , Di Vaio et al. ^[38] , Morales-Fusco et al. ^[43]
Social in port management dimensions			
Port Employee Safety & Health	SOC1	1. Number of accidents 2. Injury Rate 3. PPE Compliance rate 4. Safety Training Hours per Employee 5. Health Screening Coverage	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Gacek el al. ^[21] , Schipper et al. ^[22] , Wang et al. ^[23] , Kaup et al. ^[24] , Muangpan and Suthiwartnarueput ^[25] , Ehlers et al. ^[30] , Pallis et al. ^[33] , Budiyo and Fernanda ^[34] , Bagus and Hanaoka ^[40] , Zhang et al. ^[44]
Gender Diversity in Port Workforce	SOC2	1. Overall Female Employee Ratio 2. Female Managers or Supervisors 3. Gender Diversity Policy Implementation	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Muangpan and Suthiwartnarueput ^[25] , Ehlers et al. ^[30] , UNCTAD ^[32] , Zhang et al. ^[44]
Human Rights Compliance in Port Labor Practices	SOC3	1. Number of Human Rights Violation Complaints Received 2. Existence and Implementation of Human Rights Policy	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25]

Table 1. Cont.

Indicator	ID	Example of Measurement Variable	Reference
Port Employee Turnover	SOC4	1. Employee Turnover rate 2. New number of employees	Gu et al. ^[10] , Kim and Shin ^[45] , Özdemir ^[46] , Mwakiluma ^[47] , Dumale and Asawo ^[48]
Non-Discrimination Practices in Port Employment	SOC5	1. Existence of Anti-Discrimination Policy 2. Discrimination Complaints Received 3. Diversity in Hiring	World Federation of Exchanges ^[17] , Ehlers et al. ^[30] , UNCTAD ^[32] , Zhang et al. ^[44] , Lalconi ^[49]
Port Security Compliance	SOC6	1. Number of Security Incidents 2. ISPS Compliance 3. Cybersecurity Breaches	Gu et al. ^[10] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25] , Morales-Fusco et al. ^[43] , Junior et al. ^[50] , Ha and Kim ^[51] , Lim et al. ^[52]
Port Social Contribution Impact	SOC7	1. Number of Community Development Projects 2. Amount of Financial Contributions to Charity (Baht) 3. Number of Local Employment Creation 4. Number of Sustainability Projects Supported	Gu et al. ^[10] , Dos and Pereira ^[18] , Muangpan and Suthiwartnarueput ^[25] , UNESCAP ^[31] , UNCTAD ^[32] , UNCTAD ^[39] , Moeremans and Dooms ^[53] , Pedraza-Rodríguez et al. ^[54] , Tijan et al. ^[55]
Port Training and Education Effectiveness	SOC8	1. Training Hours per Employee 2. Number of Skills Development Programs Implemented	Makkawan and Muangpan ^[5] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Schipper et al. ^[22] , Muangpan and Suthiwartnarueput ^[25] , Hinkka et al. ^[56]
Port Community Engagement Mechanism	SOC9	1. Number of community engagement activities 2. Existence of a local community engagement policy 3. Community satisfaction score	Gu et al. ^[10] , Dos and Pereira ^[18] , Muangpan and Suthiwartnarueput ^[25] , Morales-Fusco et al. ^[43]
Governance in port management dimensions			
Port Financial Management Performance	GOV1	1. Budget Execution Rate 2. Debt-to-Asset Ratio 3. Financial transparency rating 4. Debt-to-asset ratio	Gu et al. ^[10] , Dos and Pereira ^[18] , Muangpan and Suthiwartnarueput ^[25] , UNCTAD ^[39] , Morales-Fusco et al. ^[43]
Port Operational Management Performance	GOV2	1. Average Vessel Turnaround Time 2. Berth Occupancy Rate 3. Crane Productivity 4. Container Throughput	Gu et al. ^[10] , Dos and Pereira ^[18] , Muangpan and Suthiwartnarueput ^[25] , Morales-Fusco et al. ^[43]
GDiversity and Independence of Port Board Members	GOV3	1. Percentage of Independent Directors on the Port Board 2. Conflict of Interest Disclosure (Yes/No) 3. Percentage of Female Directors	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Dos and Pereira ^[18] , Jugovic et al. ^[57]
Ethics and Anti-Corruption in Port Management	GOV4	1. Number of reported corruption and ethics cases 2. Existence of Anti-Corruption Policy 3. Percentage of employees trained in anti-corruption and port business ethics	Gu et al. ^[10] , Dos and Pereira ^[18] , Muangpan and Suthiwartnarueput ^[25] , Ehlers et al. ^[30] , Zhang et al. ^[44] , Sitompul ^[58] , Meimaris ^[59] , Roh et al. ^[60]

Table 1. Cont.

Indicator	ID	Example of Measurement Variable	Reference
Data Privacy Management in Port Operations	GOV5	1. Number of data breaches or privacy incidents reported 2. Existence of a data privacy policy 3. Percentage of staff trained on data privacy protocols	Gu et al. ^[10] , World Federation of Exchanges ^[17] , Heilig and Voß ^[61] , Kenyon et al. ^[62] , Roh et al. ^[63]
External Assurance in Port Management	GOV6	1. Existence of third-party assurance (i.e. ISO, CPA) 2. Auditor accreditation and independence	Makkawan and Muangpan ^[5] , World Federation of Exchanges ^[17] , Muangpan and Suthiwartnarueput ^[25] , Animah and Shafiee ^[64] , Chlomoudis et al. ^[65]
Socioeconomic Compliance in Port Operation	GOV7	1. Number of violations related to labour or community impact laws 2. Number of community complaints related to port operations 3. Total amount of penalties related to socioeconomic non-compliance	Gacek et al. ^[21] , Wang et al. ^[23] , Khorram ^[28] , UNCTAD ^[39] , Sitompul ^[58] , Meimaris ^[59] , Roh et al. ^[60]
Emergency Preparedness in Port Operations	GOV8	1. Existence of an up-to-date Emergency Response Plan 2. Percentage of port staff trained in emergency response 3. Number of emergencies causing port operation disruption	Muangpan and Suthiwartnarueput ^[25] , Di Vaio et al. ^[38] , Yukun et al. ^[66] , Liu and Zhang ^[67] , Zhu et al. ^[68]
Port Innovation and Technology Advancement	GOV9	1. Number of Innovation Projects Initiated 2. Budget Allocation for Innovation (Baht) 3. Number of Smart Port Project Implementation	Makkawan and Muangpan ^[5] , UNESCAP ^[31] , UNCTAD ^[39] , Niu et al. ^[69] , Cavalli et al. ^[70] , Molavi et al. ^[71] , Sahraoui et al. ^[72] , Bourgioukou ^[73]
Port Business Risk Management	GOV10	1. Existence of enterprise risk management (ERM) 2. Number of identified and assessed business risks 3. Frequency of business risk management review	Wang et al. ^[23] , UNESCAP ^[31] , UNCTAD ^[39] , Papastergiou et al. ^[74] , Lai et al. ^[75] , Ono et al. ^[76] , Juliza and Anggiat ^[77]
Transparency in Port Stakeholder Communication	GOV11	1. Existence of stakeholder engagement policy 2. Publication of ESG or sustainability report 3. Timeliness and accessibility of public disclosures	Gu et al. ^[10] , Wang et al. ^[23] , Ehlers et al. ^[30] , UNESCAP ^[31] , UNCTAD ^[39] , Bagus and Hanaoka ^[40] , Dias et al. ^[41]

3.1.3. Validate ESG Indicators

To validate and operationalize the 29 ESG indicators synthesized in **Table 1**, this study employed a document analysis method across all 115 related academic articles published between 2015 and 2025, as presented in **Figure 2**. The keywords derived from

each ESG indicator were used as coding terms and were quantitatively analyzed using NVivo software to facilitate a directed content analysis, guided by a predefined set of 29 ESG indicators identified during the literature review. To ensure consistency and relevance in the coding process, specific keywords were developed for each indicator based on its conceptual definition. These key-

words were used to search for and identify meaningful excerpts within the documents. For example, terms such as “GHG emissions” were used to locate content relevant to greenhouse gas reduction (ENV1), while “safety” and “health” were linked to employee welfare (SOC1). This keyword-driven approach enabled a systematic method for categorizing data across environmental, social, and governance dimensions. The coding results were reviewed for consistency and accuracy before further analysis. The frequency and distribution of coded segments were then quantified and visualized to highlight which indicators appeared most frequently across the literature. This quantification helped determine the relative emphasis placed on different ESG themes in the port sector and guided the development of the proposed ESG framework.

As part of the analysis, two key conceptions were developed to present the findings. **Figure 3** presents

the number of articles in which each ESG indicator was identified. The figure indicates the distribution of ESG indicators across the 115 reviewed articles. Indicator GOV9 (Port Innovation and Technology Advancement) appeared in the highest number of articles, while SOC4 (Employee Turnover Rate) and SOC5 (Non-Discrimination Practices in Port Employment) were the least represented.

Figure 4 shows the total number of coded references for each ESG indicator. This figure presents the overall frequency with which each indicator appeared in the dataset, based on keyword coding from document analysis using NVivo. Like **Figure 3**, Indicator GOV9 (Port Innovation and Technology Advancement) also had the highest total number of references, while SOC4 (Employee Turnover Rate) and SOC5 (Non-Discrimination Practices in Port Employment) had the lowest.

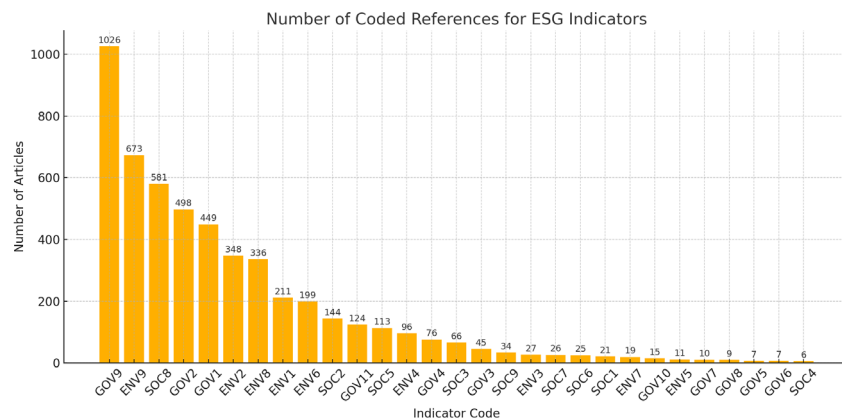


Figure 3. Number of articles by ESG indicator code.

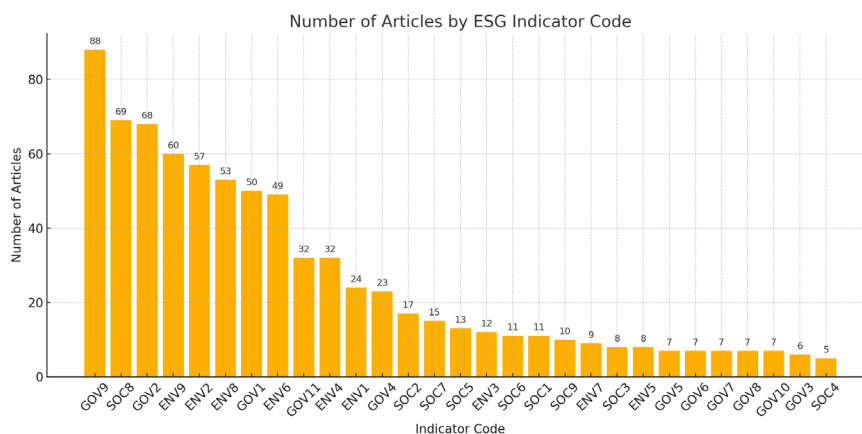


Figure 4. Number of coded references for ESG indicators.

This study relied solely on document analysis as an initial step to synthesize existing knowledge and develop a foundational ESG framework. We acknowledge that incorporating triangulation techniques, such as expert interviews or practitioner surveys, could enhance methodological robustness. This limitation is further discussed in Section 4.

3.1.4. The Relationship Among ESG Dimensions in Sustainable Port Management

Based on a comprehensive review of existing literature through document analysis, the relationship among the three ESG dimensions—Environmental, Social, and Governance—in port management is not linear but cyclical and supports other dimensions. This view is consistent with earlier research, which points out that integrating all three ESG dimensions—environmental, social, and governance—is key to encouraging sustainability in operationally complex areas such as

port management^[42,78]

As shown in **Figure 5**, environmental practices influence social outcomes by improving public health and the quality of life in the local community^[6,79,80]. Social factors can also shape governance by fostering accountability, equity, and trust among stakeholders^[42,81]. Strong governance mechanisms—through transparency, stakeholder engagement, and anti-corruption policies and measurements—then guide and enhance environmental performance^[82–84]. This creates a dynamic cycle where each dimension supports the others. All three ESG dimensions ultimately converge to drive port sustainability as strong pillars.

This cyclical interrelationship highlights the importance of managing the feedback loops among environmental, social, and governance in port management dimensions. As evidence suggests, ports that address these dimensions in an integrated manner are more likely to achieve resilient and sustainable operational outcomes.

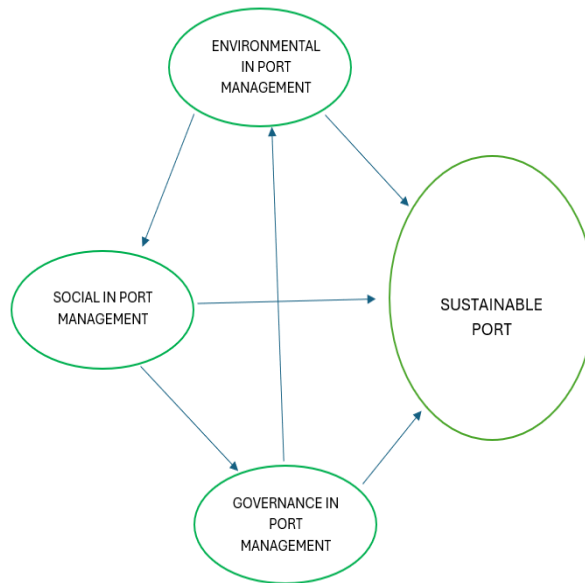


Figure 5. The relationship among ESG dimensions in sustainable port.

3.2. Port Sustainability Framework in Thailand

To establish a foundation for an ESG-based port sustainability framework, this study identified 29 key indicators through document analysis. **Figure 5** illustrates the cyclical relationship among ESG in port

management dimensions: environmental practices encourage social outcomes, social conditions shape governance, and governance, in turn, impacts environmental performance. This interconnected loop demonstrates that ESG components function as an integrated system. These indicators, along with the conceptual insights from **Figure 5**, were integrated and then syn-

thesized using a framework construction approach to develop the structure, as shown in **Figure 6**. The resulting framework reflects thematic categorization and conceptual integration. It is presented as a reflective SEM model in which each ESG dimension is treated as a latent construct measured by a set of reflective indicators. While the model is conceptual, it serves as a foundation for future empirical testing using Structural Equation Modeling (SEM) to validate interrelationships among the ESG dimensions. Accordingly, all indicators are grouped into three core port management as follows:

- Environmental port management, comprising nine indicators (ENV1–ENV9), focuses on the role of environmental practices, including GHG emissions

reduction, waste management, and resource efficiency.

- Social in port management, comprising nine indicators (SOC1–SOC9), emphasizes social responsibilities, including labour safety, diversity, human rights, and community engagement.
- Governance in Port Management, comprising 11 indicators (GOV1–GOV11), focuses on organizational transparency, ethical practices, business risk management, and technological adaptation.

Each ESG indicator is conceptually linked to its respective dimensions, which collectively support the overall goal of a Sustainable Port. This framework provides a comprehensive structure to guide port management practice in alignment with sustainability goals.

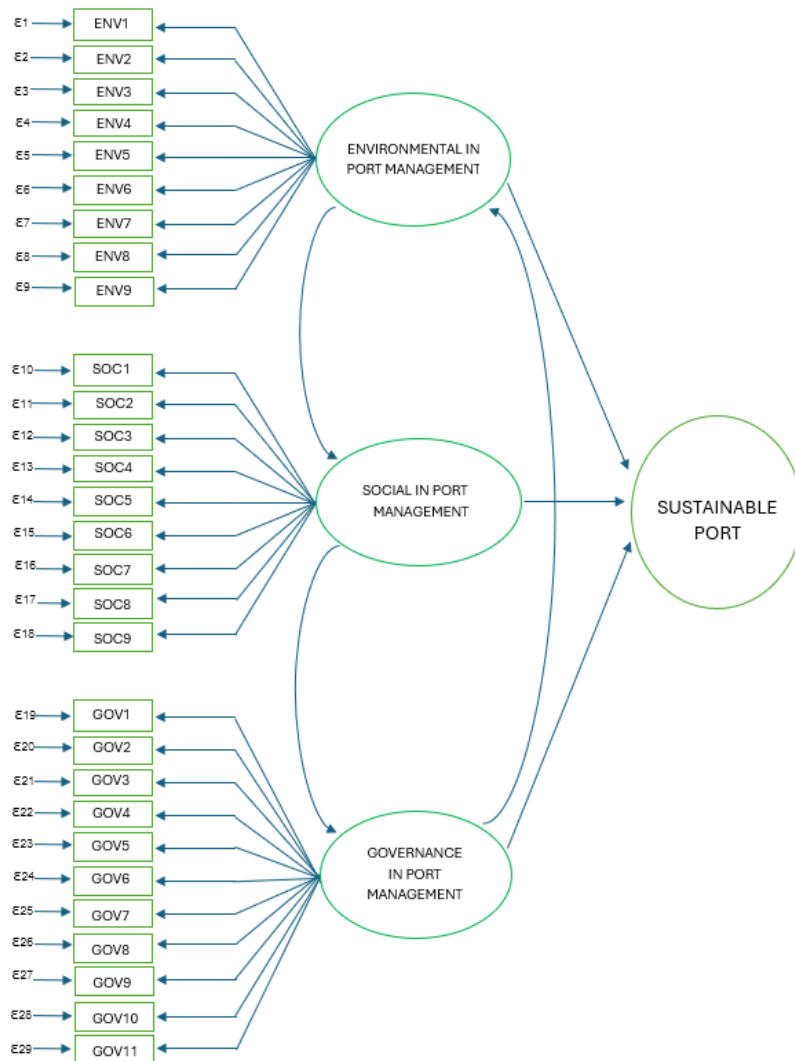


Figure 6. Conceptual framework showing interconnections among ESG dimensions in port sustainability, with indicators assigned to each dimension based on document analysis.

4. Discussion

4.1. Interpreting ESG Indicators and Dimensions

This study identifies 29 ESG indicators and provides guidelines for developing sustainability in Thai port operations that span multiple dimensions. These indicators—covering nine environmental, nine social, and 11 governance in port management, as shown in **Table 1**—reflect a broader understanding that sustainability is not limited to environmental concerns alone. The greater number of governance-related indicators suggests that transparent processes, effective business risk control, and stakeholder responsibility are essential for achieving sustainability in ports.

Figures 3 and 4 show the importance of each ESG indicator within the reviewed academic literature. Both figures exhibit a consistent trend of indicators becoming more prominent, indicating areas of greater scholarly focus in port sustainability research. Indicator GOV9 (Port Innovation and Technology Advancement) stands out in both the number of articles and the frequency of coded references. This highlights the strong academic interest in technology and digital transformation in ports—an area increasingly associated with smart ports, automation, and Industry 4.0^[85,86]. The frequent appearance of GOV9 highlights the academic view that innovation is essential to port sustainability and efficient port operations in the modern era. Like ENV9 (Environmental Management in Port Operations) and SOC8 (Training and Education Effectiveness), these were also the top-referenced indicators. This suggests a growing need for environmental policies and capacity building among port staff and stakeholders^[87,88]. The emphasis on these indicators aligns with global trends that call for environment and human capital as part of sustainability strategies^[89].

On the other hand, certain social indicators—such as SOC4 (Employee Turnover) and SOC5 (Non-Discrimination Practices in Port Employment)—were coded far less frequently. Despite their limited appearance in the reviewed literature, empirical studies have recognized their significance in influencing workforce morale, op-

erational efficiency, and equitable employment practices in port settings^[45–48]. Their low visibility may reflect either an underrepresentation in port-specific academic publications or a lack of accessible data, rather than a lack of relevance. This highlights the importance of future empirical research to capture social dimensions in port sustainability better.

In contrast, indicators like GOV1 (Port Financial Management Performance), ENV1 (GHG Emissions Reduction), and ENV2 (Waste and Pollution Management) were not only frequently mentioned but also coded with high intensity. Their prominence can be attributed to strong alignment with international regulatory frameworks and their tangible, measurable impact—attributes often emphasized in both academic research and institutional reporting. For instance, GHG reduction is closely linked to SDG 13 and is a common metric used by port authorities to demonstrate environmental performance. Likewise, financial transparency and management are essential components for organizational credibility and are often prerequisites for international investment and certification processes.

Figure 5 shows that governance in port management practices encompasses not only anti-corruption measures, data privacy management, and external assurance mechanisms, but also supports the implementation of environmental protocols and social responsibility. In parallel, environmental indicators reflect both global and local efforts to reduce GHG emissions, manage waste, and develop climate adaptation strategies. Social indicators emphasize development through labor safety, community engagement, and human rights—critical factors in maintaining a social license to operate. Recognizing these interrelationships enables stakeholders to adopt a systems-oriented approach to sustainability, helping Thai ports align more closely with national SDG strategies.

4.2. Comparison with Previous Studies

Previous studies have contributed significantly to the development of ESG frameworks in port management. For example, Dos Santos and Pereira^[18] proposed an ESG performance scoring method tailored for responsible investment in port operations. Gu et al.^[10]

conducted an empirical analysis of ESG adoption across China's port industry, highlighting national-level efforts to integrate sustainability into port governance. Serra et al.^[20] reviewed how traditional key performance indicators (KPIs) are evolving to incorporate environmental and safety considerations, reflecting a shift toward sustainable port performance. Similarly, Villabruna et al.^[19] examined barriers and strategies for green investments in ESG practices among seaport companies, revealing that even where ESG awareness is growing, implementation remains fragmented—often due to unclear frameworks, limited internal resources, and lack of integration across dimensions. However, most of these studies tend to analyze each ESG dimension in isolation and rarely explore how environmental, social, and governance factors interact as a system. In the context of Southeast Asia, studies remain limited and often emphasize only the environmental aspect of sustainability. For instance, a recent study on Northport in Malaysia proposed a conceptual model for green port practices, focusing primarily on environmental strategies such as climate change mitigation and digitalization^[90]. Similarly, a study of dry-bulk terminals in Port Klang applied a fuzzy-Delphi method to identify green performance indicators, placing strong emphasis on environmental governance and stakeholder cooperation^[91]. In Thailand, the work of Sankla and Muangpan^[92] developed a conceptual model of smart and sustainable port performance that integrated ESG concepts; however, the emphasis remained largely on technological advancement and environmental performance, with less attention to social and governance mechanisms.

4.3. Implications for Port Operations

The ESG framework developed in this study (**Figure 6**) offers practical value for improving port operations in Thailand. By identifying the measurability of each indicator (**Table 1**), port authorities and terminal operators will have a structured tool for assessing their current performance and setting sustainability targets. The framework transforms broad ESG principles into actionable elements that organizations can monitor, evaluate, and report regularly. While the framework is grounded in document analysis, future studies may

complement this approach with empirical methods—such as stakeholder interviews or on-site validation—to deepen contextual understanding and ensure the indicators are fully aligned with operational realities.

Operationally, environmental indicators such as air pollution emissions, waste management, and resource efficiency can guide ports to implement cleaner technologies and optimize energy usage. In the social dimension, indicators related to employee safety, training programs, and community engagement can inform human resource and CSR policies that strengthen community relationships and enhance workforce wellbeing. Governance indicators—such as risk management systems, stakeholder communication, and transparency practices. These mechanisms are fundamental in increasing regulatory scrutiny and public expectations. By using this ESG framework, ports can better align their operations with national policy priorities and international sustainability benchmarks while also enhancing competitiveness and investor confidence, including customer confidence.

In addition to its practical use in port operations, the ESG framework can guide policy development. Regulators, such as the Thai port authority or marine department, may utilize it to establish ESG compliance standards, incorporate sustainability performance into port or terminal licensing, or offer incentives to operators who meet these standards. Embedding the framework in national maritime policies could promote consistent ESG adoption across Thai ports, supporting sustainable development and international competitiveness.

5. Conclusion

This study contributes to sustainable port development by identifying 29 ESG indicators that are suitable for the Thai port context. These indicators—encompassing environmental, social, and governance aspects in the port management dimension—form the framework that illustrates how different ESG dimensions are interlinked within port operations. The findings suggest that the environmental (E) dimension influences the social (S) dimension, which in turn affects governance

(G) in port management. Subsequently, governance contributes back to environmental management, forming a cyclical relationship that reinforces sustainable port development.

Theoretically, this study advances ESG literature in the port sector by offering a structured and interdependent framework, moving beyond the common practice of treating ESG dimensions in isolation. It deepens the understanding of how environmental, social, and governance components interact as a system—an area often underexplored in existing port sustainability studies.

Practically, the proposed ESG framework connects sustainability concepts with real-world applications. It provides port authorities, port/terminal operators, and industry stakeholders with a valuable tool to evaluate current practices, set clear targets, and ensure that port development aligns with both national sustainability strategies and international frameworks, such as the UN Sustainable Development Goals (SDGs). In practice, this framework can serve as a strategic reference for key regulatory and operational bodies. The Marine Department may adopt the indicators to define ESG performance standards for terminal operator licensing and monitoring. The Port Authority of Thailand can use the framework to update sustainability benchmarks and support ESG-aligned development plans across Thai ports. Terminal operators, especially in the private sector, may apply the indicators to assess internal operation practices and improve long-term management. Strategically, aligning operational policies with this framework could enhance the competitiveness of Thai ports and strengthen their position in the global logistics network.

Future research should build upon this study by validating the proposed ESG indicators and their interrelationships. One promising approach is Structural Equation Modeling (SEM), which allows for the testing of both measurement validity and causal relationships among latent constructs such as environmental, social, and governance dimensions. Applying SEM would not only confirm the reliability of each indicator but also provide statistical evidence of how these dimensions influence one another within port operations. This empirical validation could bridge the gap between con-

ceptual frameworks and operational practices, offering a more robust basis for ESG-based policy formulation. Ultimately, a validated structural model would enhance decision-making for port authorities and policymakers seeking to implement sustainability strategies aligned with Thailand's national and global goals, such as SDGs.

Author Contributions

Conceptualization, K.M. and T.M.; methodology, K.M. and T.M.; validation, T.M. and J.S.; formal analysis, T.M. and J.S.; investigation, J.S.; resources, K.M.; data curation, K.M.; writing—original draft preparation, K.M.; writing—review and editing, T.M. and J.S.; visualization, J.S.; supervision, T.M.; project administration, K.M. and T.M.; funding acquisition, J.S. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical considerations.

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Conflicts of Interest

The authors declare no conflict of interest.

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