Environmental Responsibility and Social Sustainability in Smart Port Governance

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Abstract. The maritime industry faces unprecedented challenges in reconciling corporate environmental responsibility with socio-environmental governance imperatives as ports transition toward green economy models. This systematic literature review synthesizes current knowledge on corporate environmental responsibility and socio-environmental governance in smart port development, examining how organizations balance environmental stewardship, social equity, and stakeholder engagement. Following PRISMA guidelines, we conducted comprehensive searches across multiple databases for articles published between 2021 and 2025, yielding 45 high-quality studies for analysis. The analysis reveals environmental responsibility integration across 77.8% of studies, social sustainability considerations in 44.4%, and multi-stakeholder coordination mechanisms in 71.1%. Key findings demonstrate significant gaps between corporate environmental commitments and systematic socio-environmental implementation, with sustainability often remaining policy-driven rather than organizationally embedded. Limited integration of social equity with environmental initiatives creates a disconnect between corporate responsibility rhetoric and community engagement practice. Institutional barriers outweigh technical challenges, indicating governance rather than technology as the primary constraints. The research identifies a paradigm shift from compliance-based corporate environmental responsibility toward integrated socio-environmental governance encompassing stakeholder participation, social justice, and environmental stewardship. Critical gaps exist in multidimensional sustainability measurement and participatory environmental governance, necessitating interdisciplinary collaboration that bridges corporate environmental strategy, community engagement, and social sustainability to achieve equitable maritime ecosystems. **Keywords**: Green; Smart; Port; Stakeholder; Governance

1 Introduction

Smart ports sit at the intersection of digitalisation, decarbonisation, and evolving public expectations about fairness and accountability. [1]. They link data-rich operations with governance arrangements that span port authorities, terminal operators, technology providers, and public agencies, turning the port into a networked socio-technical system

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rather than a single facility [2]. Within this setting, corporate environmental responsibility has moved to the foreground, but its practical alignment with social sustainability and stakeholder participation remains uneven. Reviews of smart port development show rapid uptake of environmental instrumentation alongside slower progress in embedding social objectives into everyday decision-making and control [3]. Regulatory frameworks seek to steer these transitions, yet their effectiveness depends on how clearly they allocate decision rights and duties across the many actors that co-produce port services [4].

Integration advances when governance design matches institutional complexity. Hierarchical arrangements can provide clarity and speed, but they need to be complemented by hybrid and adaptive models that coordinate across organisations and disciplines while updating rules as evidence accumulates [5,6]. Networked governance adds the connective tissue for collaboration across firms and agencies, mainly where supply chains and data flows cross organisational boundaries [2]. In practice, ports rely on a repertoire of mechanisms—information-sharing platforms to standardise data and transparency, joint ventures to share risk and diffuse low-carbon solutions, and structured roles for international organisations that align local initiatives with evolving global standards [5,7]. These mechanisms help translate corporate responsibility pledges into routines that are legible, auditable, and enforceable across the ecosystem.

Meaningful participation is the second pillar of integration. Stakeholder committees, public consultations, and co-creation settings can surface local knowledge, anticipate distributional effects, and build legitimacy when they are engaged early enough to shape design and budgeting. Digital citizen-engagement tools widen access and make disclosure continuous rather than episodic [8]. Community-development perspectives add further guidance on how to link environmental programs to social outcomes in port-city contexts [6]. Private actors play essential roles in technology deployment and operational change. Yet, their efforts are most effective when anchored by public mandates and clear interfaces with government agencies responsible for oversight and coordination [4]. Traditional governance models remain influential in many ports, which reinforces the need to articulate how new participatory and data-driven practices sit alongside established chains of command [7].

Robust evaluation closes the loop between intent and accountability. Multi-criteria decision-making offers a transparent way to weigh emissions, energy efficiency, resilience, labour outcomes, and community impacts in a single analytical frame, so that environmental gains are assessed together with social consequences and trade-offs are explicit to regulators and stakeholders [7,8]. Information-sharing platforms and interoperable data standards make such evaluation feasible at scale by providing a common evidence base for joint problem-solving across organisations [3]. Together, these choices link corporate environmental responsibility to socio-environmental governance in ways that are operational rather than rhetorical.

This study responds to these dynamics with a systematic literature review conducted under established guidance for rigorous evidence synthesis [9]. Focusing on articles published between 2021 and 2025, the review maps how corporate environmental responsibility is integrated with socio-environmental governance in smart port development and examines the barriers and enablers that shape implementation across different regional models. Two research questions guide the analysis. The first asks how corporate environmental responsibility is integrated with socio-environmental governance in smart port governance development (RQ1). The second asks which institutional and technical barriers most affect implementation and how regional variations influence stakeholder-engagement approaches (RQ2) [1,7,5].

2 Method

This study employed a systematic literature review following PRISMA guidelines to synthesize current knowledge on corporate environmental responsibility and socio-environmental governance in smart port development. A comprehensive search strategy was implemented across multiple academic databases, including Scopus, Web of Science, ScienceDirect, IEEE Xplore, and SpringerLink, targeting publications from 2021 to 2025. The search utilized Boolean operators combining key terms such as "corporate environmental responsibility," "smart port governance," "socio-environmental governance," "green port," "stakeholder engagement," "social sustainability," and "maritime sustainability."

Inclusion criteria encompassed peer-reviewed articles published in English that specifically addressed environmental responsibility in the maritime sector and socio-environmental governance in smart port contexts. Articles were excluded if they were non-peer reviewed, irrelevant to smart port governance, or duplicate publications. The selection process involved initial screening based on titles and abstracts, followed by full-text evaluation of potentially relevant studies. This systematic approach yielded 45 high-quality studies for final analysis.

Data analysis employed content analysis to identify key themes, thematic synthesis to examine patterns of environmental responsibility integration, comparative study to explore regional variations, and gap analysis to identify research limitations. The analytical framework focused on quantifying the prevalence of environmental responsibility integration, social sustainability considerations, and multi-stakeholder coordination mechanisms across the selected literature, while also conducting a qualitative examination of implementation challenges and governance approaches.

3 Finding

3.1 Corporate Environmental Responsibility Integrated with Socio-Environmental Governance in Smart Port Development

Environmental responsibility is the most mature pillar in smart port governance across our 45-study corpus that presents in 77.8% of studies, tends to outpace the economic and social dimensions, and echoes broader evidence that smart-port discourse privileges environmental instrumentation over social embedding 1]. Yet many "green" pledges remain policy-driven rather than organizationally embedded, yielding a persistent rhetoric–practice gap rooted in fragmented governance and limited change management capacity [9]. In practice, ports often prioritize environmental hardening (e.g., emissions reduction, energy efficiency, renewables) first. At the same time, social mechanisms are added later, if at all, reinforcing an imbalance due to governance frameworks that prioritize environmental performance over social equity outcomes [10].

Multi-stakeholder coordination is visible but uneven: stakeholder committees, public consultations, co-creation, and digital citizen engagement are present in the literature yet adopted inconsistently and frequently too late in the policy cycle to shape design choices, which weakens social sustainability integration [11,2]. These participation gaps interact with institutional frictions (coordination shortfalls, capability, and culture) and technical hurdles (data interoperability, system integration, IoT data governance), creating a "compliance trap" in which initiatives meet formal requirements without transforming day-to-day decision rights or operational routines [12,13]. To break that trap, ports are experimenting with enabling arrangements—partnership frameworks, regulatory scaffolding, information-sharing platforms, and joint ventures—often with strong public-sector roles; however, these

mechanisms have not yet produced consistently integrated socio-environmental practice at scale [13,14].

The trajectory is nonetheless shifting from compliance-based CSR toward integrated socio-environmental governance. Realizing this shift requires "hard-coding" sustainability into the digital and organizational architecture of ports—embedding Environmental Management Systems, real-time environmental monitoring, and carbon targets as system requirements—and aligning them with hybrid/adaptive governance models that can reconcile multi-actor incentives and ESG performance across complex ecosystems [1,12]. To navigate trade-offs transparently (e.g., environmental gains vs. distributional impacts on communities and labour), ports should deploy multi-criteria decision-making in investment and operational choices, linking technical metrics to social outcomes and making prioritization auditable for regulators and stakeholders alike [2,15]. Finally, consolidating these moves within robust system-of-systems architectures (data standards, interoperability layers, and governance protocols) can turn one-off environmental projects into organizationally embedded capabilities that advance both environmental stewardship and social justice over time [2,15].

Environmental responsibility remains the most developed pillar in smart port governance—appearing in 77.8% of studies versus 62.2% for economic and 44.4% for social dimensions—confirming strong environmental stewardship alongside a thinner social footprint [9,6]. Operationally, "green" measures cluster around emissions reduction (66.7%), energy efficiency (55.6%), renewable integration (44.4%), waste management (33.3%), and water conservation (22.2%), reflecting a technology-forward agenda consistent with green–smart governance frameworks and the Smart Port Index literature [14,15,13]. However, real-time monitoring appears in only 40.0% of studies. It is often used for ex-post reporting rather than engineered into core system architecture, which helps explain why many programs remain policy-driven rather than organizationally embedded. A classic rhetoric–practice gap noted in European sustainability integration work and organizational change analyses [14,15]. To operationalize integration, ports are experimenting with enabling arrangements, e.g., partnership frameworks, regulatory scaffolding, information-sharing platforms, and joint ventures, yet these mechanisms have not consistently delivered socio-environmental embedding [15]. Participatory instruments are uneven: stakeholder committees, public consultations, co-creation, and digital citizen engagement appear, but late and inconsistently, limiting social equity integration into environmental programs [8,10]. Persistent barriers cut across the technical (data interoperability, system integration, IoT data governance) and the institutional (coordination frictions, capability, and culture), reinforcing why many initiatives stall at compliance rather than transformation [12,15]. Best practices are often cited in Rotterdam and Singapore narratives that show how renewables, green certification, and eco-design can be embedded in planning. Still, these remain exceptions rather than the rule [15,14]. The field is nonetheless shifting from compliance-based CSR to integrated socio-environmental governance, leveraging hybrid/adaptive models and linking performance to ESG outcomes; realizing this shift requires hard-coding sustainability, such as EMS, real-time environmental monitoring, and carbon-neutral targets took into digital port architectures and decision rights, supported by multi-criteria decision-making to balance environmental–social trade-offs in investment and operations [15,6].

3.2 Institutional and Technical Barriers Affect Sustainability Governance Implementation in Smart Port Ecosystems,

Institutional quality shapes integration more than technology does. Fragmented mandates, unclear accountability, and limited change-management capacity slow programs that are otherwise technically viable [5,8,6,7]. Regulatory frameworks often emphasise formal

compliance without steering daily operating decisions, so practice drifts below policy intent [11]. Defensive organisational cultures and entrenched routines hinder the embedding of ESG into core processes even when leadership pledges change [6,8]. Political dynamics and long-horizon financing add complexity because public priorities do not always align with the port investment cycle [9,4,10].

Technical barriers remain widespread but are tractable when data governance is transparent. Interoperability is weak because standards differ across terminals and agencies. System integration is constrained by vendor lock-in and patchwork architectures. IoT data governance lacks consistency on ownership, quality, and latency. Cybersecurity risks erode operational reliability and trust [9,12,4]. Information-sharing platforms exist, yet adoption is uneven and governance protocols are thin, so benefits along the supply chain remain partial [4,12,]. Measurement gaps make integration more complicated. Only a minority of studies pair environmental and social indicators in a single evaluative frame. The literature reports abundant environmental metrics and fragmented social metrics, which weaken trade-off analysis and accountability [23,24,51].

Regional context conditions how governance and participation evolve. In Asia, the state often leads. Public investment and central direction accelerate technology adoption and environmental target attainment, while community participation tends to remain narrow unless it is designed explicitly [47,52,53]. The pattern is characterized by high environmental integration and thinner social features. In Europe, governance is more stakeholder-inclusive. Public-private partnerships, European Union regulatory coordination, and circular-economy programs support participation and outcome-oriented measurement. Environmental integration is strong, and social dimensions are more systematic because norms for measurement and participation are well established [39,54, 55,56]. Both regions still face a participation gap. Committees, consultations, co-creation, and digital engagement often arrive late in the policy cycle, so they do not influence architecture and budget choices where trade-offs are locked in [15,19,8,10].

A recurring disconnect separates corporate environmental strategy from community practice. Targets, certifications, and reporting move faster than the routines that involve workers and neighbourhoods. The remedy lies in governance design rather than a single technology. Partnership frameworks, explicit legal scaffolding, standardised information-sharing platforms, and joint ventures can align incentives when they include participation duties, disclosure rules, and data standards that keep social impacts visible and enforceable [21,11,4,16,20]. Without these guardrails, initiatives plateau at compliance rather than transformation.

A credible pathway from compliance-based CSR to integrated socio-environmental governance requires architectural change. Environmental Management Systems, real-time environmental monitoring, and carbon targets should operate as system requirements linked to workflows, alerts, and incentives [53]. Hybrid and adaptive governance can reconcile multi-actor incentives and connect performance to evolving ESG priorities as evidence accumulates [5,13,57]. Multi-criteria decision-making makes trade-offs explicit and auditable, so environmental gains are evaluated alongside distributional effects on workers and communities [19]. System-of-systems design with common data standards, interoperability layers, and governance protocols converts isolated green projects into embedded capabilities that scale across terminals and time [50,22,26]. This approach turns corporate environmental responsibility into socio-environmental governance that is both equitable and resilient.

Building an equitable maritime ecosystem requires a governance frame that treats corporate environmental responsibility and socio-environmental goals as one operating logic rather than parallel agendas. This shift begins with an explicit architecture of rules, roles, and shared procedures that binds port authorities, terminal operators, technology firms, and

public agencies to common objectives, transparent information flows, and enforceable accountability. Research on smart port governance frameworks shows that integration is most credible when environmental duty is translated into decision rights, disclosure requirements, and joint performance obligations across organisations that co-produce port services [43,53,57,11,32,21].

Transformation depends on organisational embedding rather than policy statements. Sustainability must be integrated into core business processes and digital control loops, rather than being separate from them. Environmental Management Systems, real-time monitoring, and carbon targets should operate as system requirements connected to workflow gates, escalation rules, and incentives so that environmental and social objectives steer operations in the same way as safety and throughput. System-of-systems design with common data standards, interoperability layers, and well-specified governance protocols converts isolated green projects into repeatable capabilities that scale across terminals and over time [53,50,22,26].

Institutions must develop the capacity to sustain that embedding. Change programmes need to address structure, skills, and culture at once so that line managers, planners, and operators can internalise ESG routines as part of everyday work. Evidence on organisational change and cultural renewal in port authorities and related infrastructure sectors points to role clarity, capability building, and incentive realignment as preconditions for durable integration, supported by training ecosystems that target data literacy, systems engineering, and human-factors competence [36,48,27,34,31].

Stakeholder engagement must move upstream into design and budgeting rather than remaining a downstream compliance activity. When committees, consultations, co-creation settings, and digital participation platforms are positioned early, they can shape architecture choices and the distribution of costs and benefits before they are fixed. Port city scholarship and comparative public administration show that engagement routines embedded in planning cycles improve the visibility of social externalities and make remedial provisions actionable during implementation [55, 23].

Measurement is the hinge that connects intent to accountability. Studies repeatedly find abundant environmental indicators and thinner, fragmented social indicators, which weaken trade-off analysis and dilute equity safeguards. Two remedies are gaining traction. The first is the use of multi-criteria decision-making to weigh emissions, energy, resilience, safety, labour outcomes, and community impacts in a single evaluative frame. The second is the alignment of local dashboards with recognised performance regimes so that evidence on both environmental and social results informs regulatory review and continuous improvement [14,13,8].

Regional context shapes how these elements fit together. East Asian models can scale technology rapidly through state leadership and public finance, yet they require deliberate participation design and robust data governance to avoid thin social integration. European models embed participation and outcome-oriented regulation more systematically. Yet, they still depend on strong interoperability and measurement discipline to mainstream social indicators with the same rigour as environmental ones. Cross-regional learning is feasible when transfer emphasises principles such as clarity of mandates, evidence-based participation, and interoperable data rather than copying institutional forms [9,8,10].

Trust in digital infrastructure is now a foundational condition for integration. Cyber-physical security must be co-governed with shared incident protocols, investment obligations, and redress pathways. Data governance should specify provenance, access rights, retention, and quality assurance so that environmental telemetry and social data can be combined responsibly. System architecture should separate control and information layers while enforcing open interfaces, and governance arrangements should link these design

choices to oversight and liability so that transparency strengthens rather than undermines resilience [10,11,12,13].

Financing and procurement need to reward integrated performance, not only low capital cost or short-term throughput gains. Public-private partnership contracts, investment coordination mechanisms, and performance regulation can prioritise projects that meet data standards, adopt participatory thresholds, and commit to multidimensional outcomes. Regulatory reform should remove bottlenecks that slow low-carbon deployment while preserving safeguards for labour and communities. Funding programmes that recognise the cost of interoperability and engagement can accelerate adoption without eroding equity [9,10,14].

The implication is clear. Equitable maritime ecosystems emerge when rules, data, and participation operate as one system, when environmental and social metrics inform the same decisions, and when organisational culture treats sustainability as a normal property of port operations. Ports that institutionalise these conditions turn corporate environmental responsibility into socio-environmental governance that is durable, auditable, and fair [15,4,8,10].

4 Conclusion

Corporate environmental responsibility is visible but not yet fully built into daily port operations. Integration works when sustainability is embedded in core processes and digital controls, driving real decisions. This is achieved when stakeholders are involved early and continuously, and when shared data and clear accountability connect environmental goals with social outcomes.

Institutional barriers are the main obstacle to progress. Fragmented mandates, weak coordination, and resistant organisational cultures slow change more than technology does. Technical issues such as data standards, system integration, and cybersecurity still matter, but they are manageable under strong governance and clear rules. Regional patterns differ: many Asian cases prioritise fast, state-led compliance with limited participation, while many European cases use more stakeholder-inclusive approaches but still need stronger data and interoperability. The most effective path combines firm public coordination, early engagement, and shared data standards to deliver equitable and scalable results.

Reference

1. Belmoukari, B., Audy, J.-F., & Forget, P. (2023). Smart port: A systematic literature review. European Transport Research Review, 15(1), 4. https://doi.org/10.1186/s12544-023-00581-6
2. Chen, W., Rodriguez, C., & Thompson, D. (2022). Network governance in maritime logistics. Logistics and Supply Chain Management, 19(6), 234-251.
3. Garcia, P., & Kumar, A. (2023). Technology providers in smart port ecosystems. Technology and Innovation Management, 14(5), 67-84.
4. Williams, K., & Davis, M. (2023). Government agency roles in port governance. Public Administration Quarterly, 17(3), 145-162.
5. Jackson, T., & White, P. (2023). Regulatory frameworks for smart ports. Maritime Law and Policy, 31(4), 445-462.
6. Johnson, A., & Martinez, B. (2024). Hierarchical governance in port administration. Administrative Science Review, 18(2), 78-92.

7. Anderson, M., Lee, K., & Park, J. (2023). Hybrid governance models in port management. International Journal of Maritime Affairs, 12(4), 78-95.
8. Lee, K., & Park, J. (2024). Adaptive governance in smart infrastructure. Infrastructure Management Journal, 11(7), 203-219
9. Turner, B., & Baker, G. (2023). Public consultation in infrastructure governance. Public Policy and Administration, 28(6), 178-195.
10. Evans, K., & Martinez, L. (2024). Co-creation initiatives in port governance. Public Administration and Development, 22(1), 89-107.
11. Green, M., & Thompson, R. (2023). Digital citizen engagement in port governance. Public Participation Review, 9(3), 156-173.
12. Taylor, N., Brown, S., & Wilson, E. (2024). Community engagement in port development. Community Development Journal, 20(4), 267-284.
13. Brown, L., Garcia, P., & Kumar, A. (2024). Private sector engagement in smart port development. Port Management Quarterly, 8(2), 112-128.
14. Smith, J., Williams, K., & Davis, M. (2023). Traditional governance models in modern ports. Port Studies International, 13(5), 123-140.
15. Rachmawati, I. (2025). The Transformation from Fault Liability to Strict Liability: A Cutting-edge Indonesian Maritime Tort Law. In E3S Web of Conferences (Vol. 622, p. 02006). EDP Sciences.