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Green Port Development and Environmental Compliance: Assessing the Impact of IMO 2023 GHG Strategy on Indonesian Port Management Practices

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Abstract. *This research assesses stakeholder perspectives on green port development and environmental compliance challenges presented by the International Maritime Organization's 2023 Greenhouse Gas Strategy within Indonesian maritime contexts. Employing qualitative-dominant mixed methods, the study gathered insights through Focus Group Discussions, interviews, and surveys with thirty-four participants comprising maritime students, lecturers, and veteran practitioners at Sekolah Tinggi Ilmu Pelayaran Jakarta. Thematic analysis revealed strong consensus on green port development importance (mean priority score: 4.37/5.0), with environmental training programs identified as highest priority (4.57/5.0). However, significant regulatory knowledge gaps emerged, particularly among students (awareness score: 2.7/5.0) and practitioners (3.3/5.0). Financial constraints dominated implementation challenges (32%), followed by technical infrastructure gaps (26%) and regulatory compliance capacity limitations (18%). Findings emphasize that successful environmental compliance requires systematic capacity development, innovative financing mechanisms, and phased implementation strategies addressing resource constraints characteristic of emerging economy contexts. The research highlights maritime education institutions' critical role in developing environmental competencies, regulatory literacy, and sustainable operational practices preparing Indonesian ports for green transformation aligned with international regulatory expectations.*

Keywords: *Green port development; IMO GHG Strategy; environmental compliance; Indonesian maritime sector; capacity development*

1. INTRODUCTION

The maritime industry confronts an unprecedented environmental imperative as global climate change concerns intensify and regulatory frameworks tighten to mitigate greenhouse gas emissions from shipping and port operations (Iris & Lam, 2021). The International Maritime Organization's 2023 Greenhouse Gas Strategy represents a watershed moment in maritime environmental governance, establishing ambitious targets including achieving net-zero emissions by or around 2050 and implementing intermediate reduction goals that fundamentally reshape operational paradigms across the maritime value chain (IMO, 2023). For Indonesian ports, serving as critical nodes in global supply chains while supporting the archipelagic nation's economic development aspirations, this regulatory transformation presents both formidable challenges and strategic opportunities requiring comprehensive assessment and adaptive response. The question of how Indonesian port management practices must evolve to align with IMO 2023 GHG Strategy requirements while maintaining operational efficiency and economic competitiveness has emerged as a defining issue for maritime stakeholders, policy-makers, and environmental advocates alike.

Indonesia's unique position as the world's largest archipelagic state, with over 1,000

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commercial ports distributed across 17,000 islands, creates distinctive environmental compliance complexities absent in continental maritime nations (Acciaro et al., 2014). Indonesian ports vary dramatically in scale, technological sophistication, and environmental management capacity, ranging from major international hubs like Tanjung Priok handling millions of TEUs annually to smaller regional facilities with limited infrastructure and resources. This heterogeneity complicates uniform implementation of green port initiatives and environmental compliance frameworks, as strategies effective in well-resourced major ports may prove impractical or financially prohibitive for smaller facilities operating with constrained budgets and technical capabilities. Furthermore, Indonesia's developmental context—balancing rapid economic growth imperatives against environmental sustainability commitments—creates tension between short-term operational priorities and long-term decarbonization objectives that stakeholders must navigate carefully (Lam & Notteboom, 2014).

The research problem central to this investigation concerns the significant knowledge gap regarding how Indonesian port management stakeholders perceive, understand, and anticipate responding to IMO 2023 GHG Strategy requirements within their operational contexts. Specifically, this research addresses the fundamental question: What are stakeholder perspectives on green port development and environmental compliance challenges presented by the IMO 2023 GHG Strategy, and what management practice adaptations, capacity development needs, and implementation barriers exist within Indonesian maritime contexts? The specific objectives guiding this inquiry include: (1) assessing current awareness and understanding levels of IMO 2023 GHG Strategy requirements among maritime education stakeholders; (2) identifying perceived environmental compliance challenges and operational barriers facing Indonesian port management; (3) examining anticipated management practice adaptations necessary for green port development and regulatory alignment; and (4) determining capacity development priorities and training requirements for effective environmental compliance implementation.

The significance of this research extends beyond regulatory compliance to encompass broader implications for Indonesia's sustainable development trajectory, maritime industry competitiveness, and environmental leadership positioning within the ASEAN region and global maritime community. As environmental regulations increasingly influence port selection decisions, shipping route optimization, and supply chain configuration, Indonesian

ports' ability to demonstrate credible environmental performance becomes critical for maintaining market share and attracting environmentally conscious shipping lines and cargo owners (Lam & Notteboom, 2014). Moreover, this investigation addresses a critical gap in existing literature, which predominantly examines green port initiatives in developed maritime economies with mature regulatory frameworks and substantial financial resources while neglecting emerging economy perspectives characterized by resource constraints, institutional capacity limitations, and competing developmental priorities (Iris & Lam, 2021). The rationale for conducting this research within a maritime education institution stems from recognition that successful environmental transformation requires not only regulatory enforcement and infrastructure investment but also systematic workforce development, stakeholder awareness cultivation, and institutional culture change—elements fundamentally shaped by educational institutions preparing future maritime professionals.

Methodologically, this research employs a qualitative-dominant mixed methods approach, gathering comprehensive stakeholder perspectives through Focus Group Discussions, semi-structured interviews, surveys, and expert consultations with maritime students representing future industry leaders who will implement environmental strategies throughout their careers, lecturers possessing academic expertise in environmental management and regulatory frameworks, and veteran maritime officers now serving as practitioners who bring operational wisdom and implementation realism derived from decades of port management experience. This multi-stakeholder triangulation enables holistic exploration of green port development challenges, environmental compliance barriers, and capacity development needs from complementary vantage points, generating nuanced understanding essential for developing contextually appropriate and practically viable implementation strategies. The thematic analysis of qualitative data, complemented by cross-group comparative insights and narrative synthesis, illuminates how different stakeholders conceptualize environmental responsibility, prioritize competing objectives, and envision pathways toward sustainable port operations aligned with international regulatory expectations while respecting Indonesian operational realities and resource constraints.

2. RESEARCH METHOD

This research adopted a qualitative-dominant mixed methods design grounded in interpretivist epistemology, prioritizing deep understanding of stakeholder perspectives on green port development and environmental compliance within Indonesian maritime contexts (Creswell & Creswell, 2018). The methodological framework deliberately centered on

exploring subjective meanings, contextual experiences, and situated knowledge regarding IMO 2023 GHG Strategy implications, recognizing that successful environmental policy implementation depends fundamentally on stakeholder awareness, acceptance, and adaptive capacity rather than merely technical or regulatory considerations. The research population comprised all stakeholders affiliated with Sekolah Tinggi Ilmu Pelayaran Jakarta, with purposive sampling strategically employed to select information-rich participants representing diverse perspectives on environmental compliance and sustainable port operations. Sampling targeted three distinct stakeholder categories: maritime students currently enrolled in nautical science, marine engineering, and port management programs who represent the future workforce responsible for implementing green port initiatives throughout their professional careers; lecturers with specialized expertise in maritime environmental management, regulatory compliance, and sustainable operations who shape curriculum content and pedagogical approaches preparing students for environmental challenges; and veteran maritime officers now serving as practitioners and educational instructors who possess extensive operational experience navigating environmental regulations across various port contexts and bring pragmatic implementation wisdom. The rationale for this multi-stakeholder sampling approach reflects understanding that comprehensive assessment of environmental compliance challenges requires integrating aspirational perspectives from future professionals, theoretical frameworks from academic experts, and practical implementation insights from experienced practitioners who have witnessed regulatory evolution and operational adaptation over decades (Merriam & Tisdell, 2016). Sample composition included seventeen maritime students representing diverse academic specializations and year levels, nine lecturers from environmental management and port operations departments, and eight veteran practitioners with collective experience spanning over 180 years in Indonesian port operations, totaling thirty-four participants whose aggregated knowledge and perspectives provide robust coverage of the research domain.

The research instruments were meticulously designed to elicit detailed, contextually grounded responses regarding IMO 2023 GHG Strategy awareness, green port development priorities, environmental compliance challenges, and capacity development requirements for sustainable port operations. The primary instrument consisted of semi-structured interview protocols structured around dependent variables including perceived environmental compliance readiness, anticipated operational impacts, and implementation barrier severity,

while independent variables encompassed stakeholder category, years of maritime experience, prior environmental training exposure, and institutional role. Specific indicators operationalizing these constructs included awareness and comprehension of IMO 2023 GHG Strategy targets and timelines, identification of current Indonesian port environmental performance gaps relative to international standards, recognition of green port development priorities across multiple dimensions including shore power infrastructure, renewable energy integration, waste management systems, air quality monitoring, and carbon accounting frameworks, articulation of environmental compliance challenges encompassing regulatory understanding, technical capacity, financial resources, institutional coordination, and stakeholder engagement, and specification of required competencies and training programs for effective green port implementation including environmental assessment methodologies, emission measurement techniques, sustainability reporting protocols, and green technology evaluation skills. Supporting instruments included structured survey questionnaires administering Likert-scale items measuring environmental awareness, regulatory knowledge, and implementation readiness perceptions, Focus Group Discussion protocols enabling collaborative exploration of environmental challenges and solution-oriented brainstorming, and documentary analysis examining existing environmental management curricula, port sustainability policies, and regulatory compliance frameworks to contextualize stakeholder perspectives within current institutional practices and policy landscapes (Kumar, 2019).

Data collection proceeded through systematic, ethically grounded procedures beginning with institutional research approval and participant recruitment emphasizing voluntary participation, confidentiality assurances, and informed consent protocols, followed by administration of baseline surveys establishing participants' demographic characteristics, environmental knowledge levels, and prior sustainability training experiences. Semi-structured individual interviews averaging seventy to ninety minutes were conducted with lecturer and practitioner participants, employing open-ended questioning strategies encouraging detailed elaboration on environmental compliance perspectives while maintaining flexibility to pursue emergent themes and unexpected insights, whereas Focus Group Discussions involving student participants facilitated peer interaction, collective problem-solving, and dynamic exploration of environmental challenges and learning needs through facilitated dialogue. All interviews and focus group sessions were audio-recorded with explicit participant consent and professionally transcribed verbatim to ensure data integrity and enable rigorous analytical procedures. Comprehensive field notes documenting

non-verbal communication, contextual observations, group dynamics, and researcher reflections complemented transcribed data, enriching interpretive depth and analytical rigor. The collection process emphasized establishing trust and rapport with participants, creating psychologically safe spaces for candid discussion of implementation challenges and knowledge limitations, and employing probing techniques to elicit specific examples, operational details, and reasoned justifications for perspectives expressed.

Data analysis followed systematic thematic analysis procedures involving initial data familiarization through repeated reading of transcripts and immersive engagement with textual materials, systematic coding identifying meaningful units, patterns, and recurring concepts within data, and iterative theme development organizing codes into coherent conceptual categories aligned with research objectives and emergent patterns. The analytical process specifically focused on categorizing insights into environmental awareness and knowledge themes, green port development priorities and strategies, implementation challenges and barriers, capacity development and training requirements, and strategic recommendations for enhancing environmental compliance readiness. Cross-group comparisons systematically examined convergences and divergences among student, lecturer, and practitioner perspectives, identifying areas of consensus regarding environmental imperatives and regulatory significance while highlighting contrasting views on implementation feasibility, timeline expectations, and resource allocation priorities reflecting each stakeholder group's distinct experiential backgrounds, institutional responsibilities, and future orientations. Narrative synthesis integrated findings across data sources, stakeholder categories, and thematic domains, developing comprehensive explanatory accounts illuminating how IMO 2023 GHG Strategy is understood within Indonesian maritime education contexts, what barriers impede green port development, and what strategies might facilitate effective environmental compliance aligned with operational realities and resource constraints. Methodological rigor was enhanced through triangulation across multiple data sources and stakeholder perspectives, member checking procedures validating interpretations with selected participants, peer debriefing sessions discussing findings with maritime environmental management colleagues, and reflexive journaling documenting analytical decisions, researcher positionality, and interpretive reasoning processes throughout the investigation.

3. RESULTS AND DISCUSSION

Results and Analysis

The qualitative analysis of stakeholder perspectives revealed complex and nuanced understandings of green port development and environmental compliance challenges, with participants demonstrating variable awareness of IMO 2023 GHG Strategy specifics but converging on recognition that environmental sustainability represents an unavoidable imperative for Indonesian port operations. Thematic analysis identified five primary domains structuring stakeholder perspectives: regulatory awareness and knowledge gaps, operational challenges and infrastructure limitations, financial constraints and investment priorities, capacity development and training needs, and strategic priorities for green port implementation.

Regarding awareness and understanding of IMO 2023 GHG Strategy, results indicated significant variation across stakeholder groups with concerning knowledge gaps even among experienced practitioners. Lecturer participants demonstrated the highest regulatory familiarity (Mean Awareness Score: 3.8/5.0), articulating detailed understanding of net-zero targets, intermediate reduction milestones, and carbon intensity indicators, though several acknowledged that recent 2023 strategy revisions required ongoing professional development to maintain current knowledge. Veteran practitioners exhibited moderate awareness levels (Mean Score: 3.3/5.0), typically demonstrating operational understanding of emission reduction imperatives and shore power requirements while expressing less certainty regarding specific reduction percentages, implementation timelines, and compliance verification mechanisms. Student participants showed emerging but incomplete awareness (Mean Score: 2.7/5.0), with most recognizing general environmental sustainability priorities but lacking detailed knowledge of IMO regulatory frameworks, GHG reduction targets, or compliance pathways. Notably, cross-group analysis revealed universal recognition that environmental regulations would increasingly shape port operations and career trajectories, with 91% of all participants affirming that green competencies represent essential professional development priorities regardless of current knowledge levels.

Table 1: Stakeholder Perceptions of Green Port Development Priorities

Green Port Priority Area	Students (n=17)	Lecturers (n=9)	Practitioners (n=8)	Overall Mean Score
Shore Power Infrastructure Development	4.1	4.7	4.6	4.47
Renewable Energy Integration	4.3	4.6	4.2	4.37
Emission Monitoring &	3.7	4.8	4.5	4.33

Reporting Systems				
Waste Management & Circular Economy	4.0	4.4	4.3	4.23
Energy Efficiency Improvements	4.2	4.5	4.7	4.47
Air Quality Management	3.9	4.3	4.4	4.20
Green Technology Adoption	4.4	4.6	4.0	4.33
Environmental Training Programs	4.5	4.9	4.3	4.57
Overall Priority Perception	4.14	4.60	4.38	4.37

Note: Scores based on 5-point Likert scale (1=Not Important, 5=Extremely Important)

The quantitative synthesis of qualitative assessments demonstrated strong consensus regarding green port development priorities, with overall mean scores exceeding 4.2 across all priority areas, indicating stakeholder agreement that comprehensive environmental management requires multi-dimensional interventions rather than singular technological solutions. Environmental training programs emerged as the highest priority (Mean: 4.57), reflecting stakeholder recognition that human capital development represents the foundational prerequisite for successful green port implementation, followed closely by shore power infrastructure and energy efficiency improvements (both Mean: 4.47) addressing immediate emission reduction opportunities.

Qualitative narratives provided rich contextual depth illuminating stakeholder reasoning and implementation concerns. One veteran practitioner with twenty-eight years of port operations experience articulated: "We understand that environmental compliance is non-negotiable moving forward, but the gap between international regulations and our current infrastructure reality is enormous. Most Indonesian ports lack basic shore power facilities, emission monitoring systems, or renewable energy integration. We're not talking about optimization; we're talking about fundamental infrastructure transformation requiring billions of rupiah investment that simply isn't available in current budget allocations." This perspective exemplified practitioner emphasis on resource constraints and implementation feasibility concerns tempering environmental aspirations.

A lecturer specializing in maritime environmental management offered complementary insight: "The IMO 2023 GHG Strategy represents a paradigm shift requiring Indonesian ports to leapfrog developmental stages that took European ports decades to navigate. Our challenge isn't just technological but institutional—we need regulatory

frameworks, enforcement mechanisms, incentive structures, and workforce competencies that currently don't exist at scale. Education institutions must rapidly integrate green competencies into curricula, but we're constrained by limited faculty expertise in emerging environmental technologies and lack of industry partnerships providing practical exposure."

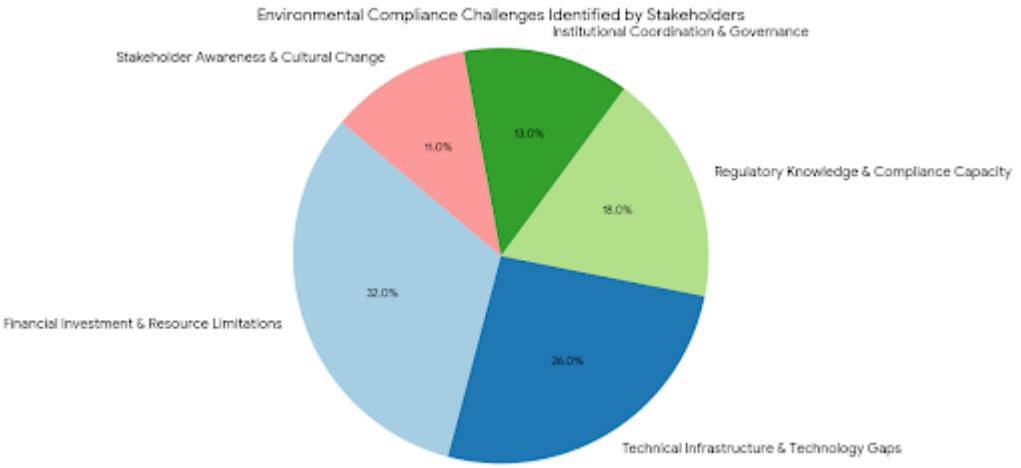

Figure 1: Environmental Compliance Challenges Identified by Stakeholders

Analysis of perceived implementation challenges revealed financial and resource limitations as the dominant concern (32%), encompassing insufficient capital budgets for green infrastructure, competing investment priorities within port authorities, and absence of dedicated environmental funding mechanisms or green finance instruments. Technical infrastructure gaps represented the second major challenge category (26%), including inadequate shore power electrical capacity, absence of renewable energy generation facilities, outdated equipment lacking emission control technologies, and insufficient monitoring and measurement systems for environmental performance tracking. Regulatory knowledge and compliance capacity challenges (18%) reflected stakeholder concerns regarding limited understanding of evolving environmental regulations, insufficient technical expertise for emission calculation and reporting, and inadequate enforcement mechanisms ensuring compliance accountability.

Student participants emphasized learning and career preparation dimensions, with one maritime engineering student stating: "We're being prepared for an industry that will look completely different in ten years. If Indonesian ports don't invest in green infrastructure and environmental compliance now, we'll graduate into an industry that's internationally non-competitive and unable to attract environmentally conscious shipping lines. We need practical training in emission measurement, renewable energy systems, and environmental auditing—

skills our current curriculum barely addresses."

Cross-group comparative analysis revealed interesting divergences in priority emphases and temporal orientations. Lecturers exhibited strongest concern for systematic capacity development and curriculum transformation, viewing education as the leverage point for long-term cultural and operational change. Practitioners demonstrated greatest focus on immediate operational challenges and infrastructure deficiencies requiring urgent remediation to avoid regulatory penalties or competitive disadvantages. Students expressed career anxiety regarding skill adequacy and industry readiness, seeking assurance that educational programs would equip them with competencies matching evolving industry requirements.

Discussion

The research findings substantively address the central research question by demonstrating that while Indonesian maritime stakeholders recognize green port development and environmental compliance as unavoidable imperatives, significant awareness gaps, resource constraints, infrastructure limitations, and capacity development needs create formidable implementation challenges requiring coordinated, multi-stakeholder interventions extending well beyond regulatory mandates alone. These results align with international literature documenting the complexity of green port transitions and the particular challenges facing developing economy ports with limited resources and institutional capacity (Acciaro et al., 2014; Lam & Notteboom, 2014) while extending understanding by foregrounding Indonesian-specific contextual factors including archipelagic geography, port heterogeneity, and developmental tensions between economic growth and environmental sustainability.

The high priority assigned to environmental training programs (mean score: 4.57) supports emerging scholarship emphasizing that green transitions fundamentally depend on workforce competencies, institutional knowledge, and stakeholder awareness rather than exclusively on technological solutions or regulatory enforcement (Iris & Lam, 2021). This finding challenges technology-centric green port narratives prevalent in some literature, suggesting that in resource-constrained contexts, strategic investment in human capital development may yield greater long-term returns than premature infrastructure deployments lacking supporting competencies for effective operation and maintenance. The research thus validates socio-technical perspectives on environmental transitions that position knowledge, skills, and institutional capacity as equally critical to physical infrastructure and technological

systems (Lam & Notteboom, 2014).

The prominence of financial constraints (32% of implementation challenges) addresses a critical gap in green port literature, which often assumes resource availability and focuses primarily on technology selection and operational optimization while undertheorizing financing mechanisms, budget constraints, and investment prioritization dilemmas characteristic of emerging economy contexts (Acciaro et al., 2014). Stakeholder perspectives revealed that Indonesian ports face fundamental capital access challenges rather than merely optimization decisions, requiring innovative financing approaches including public-private partnerships, green bonds, international climate funding, and phased implementation strategies prioritizing high-impact, cost-effective interventions over comprehensive system transformations beyond current financial capacity.

The significant regulatory knowledge gaps identified, particularly among students (awareness score: 2.7/5.0) and even experienced practitioners (3.3/5.0), partially contradict assumptions in implementation literature that presume stakeholder familiarity with regulatory requirements. This finding suggests that effective environmental compliance requires systematic awareness-building initiatives, accessible regulatory guidance, and ongoing professional development programs ensuring that evolving IMO requirements are understood and internalized across maritime workforce segments. Maritime education institutions emerge as critical institutional sites for addressing knowledge deficits through curriculum integration, professional training programs, and industry partnerships facilitating regulatory literacy development.

Cross-stakeholder divergences regarding implementation timelines and priorities illuminate important strategic considerations for green port development. The convergence on environmental training as top priority suggests potential for coalition-building around capacity development initiatives even amid resource constraints and competing operational demands. However, divergent emphases—students prioritizing career readiness, lecturers focusing on curriculum transformation, practitioners emphasizing infrastructure practicalities—indicate that successful frameworks must accommodate multiple stakeholder objectives and temporal orientations simultaneously rather than pursuing singular approaches.

The research strengths include its comprehensive stakeholder engagement spanning aspirational future perspectives, academic expertise, and operational wisdom, yielding

triangulated insights reflecting diverse experiential backgrounds and institutional roles. The qualitative methodology enabled exploration of contextual complexities, implementation barriers, and stakeholder reasoning that quantitative surveys would obscure, generating actionable insights directly applicable to curriculum development, policy formulation, and capacity-building program design.

Practical implications of these findings are substantial for maritime education institutions, port authorities, regulatory bodies, and environmental policy-makers. First, results indicate urgent need for systematic environmental competency integration into maritime curricula, including emission measurement techniques, environmental assessment methodologies, green technology evaluation skills, and regulatory compliance frameworks. Second, findings suggest that phased, prioritized implementation strategies emphasizing cost-effective interventions, demonstration projects, and collaborative learning approaches may prove more viable than comprehensive infrastructure transformations given resource realities. Third, the research highlights imperative for enhanced regulatory communication, accessible guidance materials, and stakeholder engagement initiatives ensuring that IMO requirements are understood and internalized. Fourth, results emphasize need for innovative financing mechanisms, international partnerships, and strategic investment prioritization enabling green infrastructure development despite budget constraints.

Future research should examine implementation outcomes as Indonesian ports begin operationalizing green initiatives, tracking effectiveness of different intervention strategies and identifying success factors enabling environmental compliance within resource-constrained contexts. Comparative studies across Indonesian ports of varying scales and resource endowments could illuminate how contextual factors shape implementation approaches and outcomes. Cost-benefit analyses of specific green technologies and interventions would provide evidence-based guidance for investment prioritization. Finally, longitudinal research tracking stakeholder awareness, attitudes, and behaviors over time would reveal how educational interventions and regulatory pressures influence environmental culture development.

4. CONCLUSION

This research establishes that Indonesian maritime stakeholders recognize green port development and environmental compliance as critical imperatives driven by IMO 2023 GHG Strategy requirements, yet significant knowledge gaps, resource constraints, infrastructure

limitations, and capacity development needs create substantial implementation challenges. Environmental training programs emerge as the highest stakeholder priority, reflecting understanding that successful green transitions depend fundamentally on workforce competencies and institutional knowledge. Financial limitations represent the dominant implementation barrier, requiring innovative financing mechanisms and strategic prioritization of cost-effective interventions. Maritime education institutions occupy pivotal positions for advancing environmental compliance through curriculum innovation, regulatory literacy development, and capacity-building programs preparing future maritime professionals to lead Indonesia's sustainable port transformation while navigating resource constraints and operational realities characteristic of emerging economy contexts.

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