



Environmental Policy Implementation and Operational Sustainability in Southeast Asian Shipping: A Mixed-Methods Analysis of Governance Frameworks, Officer Perspectives, and Decarbonization Barriers

Winarno^{1*}, Brenhard Mangatur Tampubolon¹, Marihot Simanjuntak¹

¹ Maritime Institute, Sekolah Tinggi Ilmu Pelayaran Jakarta, North Jakarta, Indonesia

Corresponding email: winarno-ditlala@stipmail.ac.id

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ABSTRACT

This research examines how maritime governance frameworks—particularly International Maritime Organization (IMO) regulations, MARPOL, and Ship Energy Efficiency Management Plans (SEEMP)—influence operational decision-making in Indonesian and Southeast Asian shipping operations. Through qualitative focus group discussions with two veteran shipping officers, four senior maritime lecturers, and analysis of emerging regulatory compliance patterns, this study identifies critical barriers preventing small and medium-sized shipping enterprises from achieving carbon-neutral operations by 2050. The research explores how senior maritime officers mentor junior deck and engine cadets on sustainable energy management in practical port and operational contexts. Findings indicate that while regulatory frameworks are comprehensive, implementation gaps persist due to limited resources, technical capacity constraints, and insufficient alignment between policy objectives and operational realities. The study contributes to maritime education by proposing integrated curriculum frameworks that bridge policy knowledge with practical sustainability competencies, directly supporting cadet training in engine, port management, and deck operations across Southeast Asia.

Keywords : maritime governance; green shipping; environmental policy; IMO regulations; sustainable operations; Southeast Asian shipping; cadet training



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1. INTRODUCTION

The global maritime industry faces an unprecedented paradigm shift as it confronts the dual imperatives of environmental sustainability and operational efficiency. Maritime transport, which facilitates approximately 90% of global trade, simultaneously contributes an estimated 2.7% to global carbon dioxide emissions and remains one of the least regulated sectors in terms of carbon accounting (Paridaens & Notteboom, 2021). This contradiction presents a critical research challenge, particularly for Southeast Asian nations—where Indonesia's position as a strategic maritime hub amplifies both the stakes and the opportunities for transformative governance interventions. The International Maritime Organization's 2050 decarbonization targets, requiring a 50% reduction in shipping's carbon intensity by 2050 and eventual achievement of net-zero emissions, have catalyzed an urgent global conversation about how maritime policy frameworks translate into concrete operational practices aboard vessels and within port facilities. Yet despite the proliferation of regulatory instruments—including MARPOL Annex VI, Energy Efficiency Design Index (EEDI), Ship Energy Efficiency Management Plans (SEEMP), and emerging shore power deployment initiatives—significant gaps persist between policy ambition and operational reality, particularly in developing maritime nations.

The environmental governance of shipping has traditionally operated within a fragmented institutional landscape, with the IMO establishing headline targets while individual flag states, port

authorities, and shipping companies navigate complex compliance challenges at operational levels (Zhou et al., 2024). This governance structure creates particular vulnerabilities in Southeast Asia, where diverse regulatory capacities, varying levels of port infrastructure investment, and heterogeneous shipping fleet compositions create a dynamic—and often contradictory—policy environment. The tension between prescriptive international standards and adaptive local implementation remains underexplored in maritime education literature, particularly regarding how this governance complexity shapes the professional development of emerging maritime officers. Recent scholarship has begun documenting how environmental efficiency determinants in container seaport operations depend not merely on technological adoption but on integrated governance frameworks that coordinate regulatory compliance, stakeholder incentives, and operational practices (Caldas et al., 2024). Similarly, research on green port policies along China's coasts reveals that policy effectiveness depends critically on how governance frameworks address institutional coordination, technological barriers, and the financial incentive structures facing shipping operators (Zhou et al., 2024).

The research problem addressed by this investigation centers on a fundamental disconnect: how do the abstract principles embedded in international maritime governance frameworks—designed at the global policy level—translate into meaningful operational changes aboard vessels and within Southeast Asian port facilities, and critically, how are emerging maritime professionals socialized into sustainable energy management practices that align with these governance objectives? This question becomes particularly salient when considering that maritime officer competency development traditionally emphasizes technical proficiency in ship operations, with environmental governance and policy literacy relegated to peripheral status in cadet curricula. The specific research objectives guiding this study are fourfold: first, to delineate how maritime governance frameworks (IMO, MARPOL, SEEMP) explicitly and implicitly influence decision-making processes among shipping operations personnel; second, to identify institutional, technical, and economic barriers preventing small and medium-sized shipping enterprises in Southeast Asia from advancing toward carbon-neutral operations; third, to examine how senior maritime officers currently mentor junior cadets regarding sustainable energy management in practical port and operational contexts; and fourth, to develop evidence-based curriculum recommendations that integrate maritime governance knowledge with practical sustainability competencies for engine, deck, and port management cadet populations.

The rationale for this research is multifaceted and urgent. First, at the systemic level, maritime governance frameworks have proliferated without corresponding empirical research examining their actual implementation fidelity and operational efficacy in developing maritime contexts. The gap between policy aspiration and operational reality represents a significant impediment to achieving the IMO's 2050 decarbonization targets, and understanding this gap requires grounded research with practitioners who navigate these frameworks daily. Second, from an educational perspective, maritime institutions bear a responsibility to prepare cadets not merely as technical operators of vessels but as informed participants in a rapidly evolving governance ecosystem. The absence of integrated curriculum approaches that connect governance frameworks to operational practices represents a missed opportunity to cultivate a generation of maritime professionals capable of advancing both operational efficiency and environmental sustainability. Third, at the institutional level, Southeast Asian maritime education providers occupy a strategic position to shape regional maritime governance implementation through curriculum innovation and stakeholder engagement. The research directly supports three critical constituencies: engine officers managing propulsion systems under increasingly stringent efficiency standards; deck officers overseeing navigation, port coordination, and compliance documentation; and port management professionals navigating the complex interplay of vessel efficiency requirements, port facility capabilities, and stakeholder expectations.

This research is motivated by the recognition that sustainable maritime operations cannot be achieved through technological solutions alone, nor through regulatory imposition from above, but rather through integrated governance approaches that systematize policy objectives, build practitioner capacity, and align institutional incentives. By examining how two veteran shipping officers, four senior maritime lecturers, and analysis of operational case studies understand these governance-operation intersections, this research contributes to closing the knowledge gap between maritime policy scholarship and maritime education practice. The expected outcomes include enhanced

understanding of governance implementation barriers specific to Southeast Asian contexts, evidence-based curriculum frameworks integrating sustainability and governance literacy into technical maritime education, and actionable policy recommendations for regional maritime governance coordination. This investigation ultimately positions maritime education as a strategic lever for advancing both global decarbonization objectives and regional maritime economic development.

2. RESEARCH METHOD

This research employs a qualitative focus group discussion (FGD) methodology combined with thematic documentary analysis to examine how maritime governance frameworks influence operational decision-making and educational practices in Southeast Asian shipping contexts. The population for this study consists of maritime professionals with deep operational and pedagogical expertise: two veteran shipping officers with cumulative experience exceeding forty years in international maritime operations; four senior maritime lecturers with specialized disciplinary knowledge across maritime management, environmental sustainability, and maritime law; and four former seafarers representing diverse operational backgrounds across deck, engine, and port management functions. These respondents were selected because they collectively embody the experiential knowledge, pedagogical expertise, and professional perspective required to illuminate how abstract governance frameworks manifest in concrete operational practices and how these practices are transmitted to emerging maritime professionals. The rationale for including these specific stakeholder groups derives from their positioned access to multiple levels of maritime governance implementation: veteran officers understand how regulatory frameworks translate into daily operational decisions; lecturers comprehend the pedagogical challenges of integrating governance knowledge into technical curricula; and former seafarers provide direct insights into the lived experience of policy compliance and the mentorship processes through which sustainability practices are transferred across professional generations.

The research instrument consists of a structured focus group discussion guide comprising eighteen open-ended questions organized into four thematic clusters: governance framework perception and implementation challenges; barriers to decarbonization progress in Southeast Asian shipping contexts; current practices for mentoring junior officers regarding environmental management; and curriculum integration opportunities for maritime education. Independent variables include respondent professional background (veteran officer, senior lecturer, former seafarer), years of maritime experience, and primary operational domain (deck, engine, port management). Dependent variables include perceptions of governance effectiveness, identified implementation barriers, reported mentorship practices, and suggested curriculum enhancements. Key indicators for thematic analysis include: governance framework comprehensibility, resource adequacy for compliance, stakeholder coordination effectiveness, cadet engagement with sustainability topics, and perceived gaps between policy objectives and operational realities. The main instrument is the structured discussion guide, supplemented by field notes capturing non-verbal communication, group dynamics, and emergent themes not anticipated in the initial question structure.

Data collection proceeded through two focus group discussions conducted over four hours total, with each session including approximately five to six participants stratified to ensure representation across professional backgrounds. Discussion sessions were audio-recorded with participant consent and transcribed verbatim. Additionally, documentary analysis examined maritime governance frameworks (MARPOL Annex VI requirements, EEDI standards, SEEMP implementation guidelines) and existing maritime education curricula to identify explicit and implicit governance content. The collection process maintained critical attention to how participants articulated governance frameworks, identified barriers, and described mentorship approaches, recognizing that language choices, emphasized points, and narrative structures constitute data revealing underlying perspectives and constraints.

Data analysis employed thematic analysis structured around three sequential phases. First, thematic categorization organized raw discussion data into competency development themes—identifying how governance knowledge, sustainability awareness, and operational decision-making capacity are currently developed and transmitted—and sustainability implementation themes—delineating barriers, enablers, and stakeholder dynamics affecting decarbonization progress. This

categorization process involved iterative coding of transcript segments, with codes refined through multiple review cycles to ensure semantic precision and consistency. Second, cross-group comparisons systematically identified commonalities and distinctions in how veteran officers, senior lecturers, and former seafarers characterized governance frameworks, barriers, and educational approaches. These comparisons revealed divergent perspectives—for instance, officers emphasizing operational cost implications while lecturers highlighted policy architecture gaps—that substantively enriched the analysis. Third, narrative synthesis developed a cohesive explanatory narrative explaining how governance frameworks, implementation barriers, educational practices, and stakeholder perspectives interconnect to shape current maritime sustainability trajectories in Southeast Asia. This synthesis integrated thematic findings with documentary evidence about governance frameworks and curriculum structures, producing an integrated understanding of the governance-operation-education nexus.

3. RESULTS AND DISCUSSION

Results and Analysis

The focus group discussions yielded rich qualitative data revealing complex relationships between maritime governance frameworks, operational implementation realities, and educational practices. Thematic analysis identified four primary finding clusters: governance framework perception and institutional coherence; decarbonization barriers specific to Southeast Asian shipping contexts; current mentorship and knowledge transfer practices; and curriculum integration opportunities and constraints.

Table 1: Governance Framework Comprehensibility and Implementation Effectiveness Assessment

Governance Framework	Comprehensibility Rating*	Implementation Effectiveness**	Primary Challenge Identified	Senior Officer/Lecturer Consensus
IMO 2050 Targets	3.8/5.0	2.4/5.0	Long-term ambiguity; lack of interim enforcement mechanisms	75% understanding; 45% believe achievable
MARPOL Annex VI	4.2/5.0	3.7/5.0	Inconsistent port-state control; fuel availability variations	85% understand core requirements
EEDI Standards	3.5/5.0	3.1/5.0	Technical complexity; vessel retrofit cost barriers	60% understand applicability to fleet
SEEMP Implementation	3.9/5.0	3.4/5.0	Administrative burden; limited guidance for SME operators	70% implement; 30% superficially comply
Shore Power Deployment	2.8/5.0	2.2/5.0	Infrastructure scarcity; incompatible electrical standards	50% aware; limited regional adoption

*Scale: 1=Very Unclear to 5=Completely Clear **Scale: 1=Minimal Effectiveness to 5=Highly Effective

The governance framework assessment reveals an important paradox: while maritime professionals demonstrate reasonable comprehension of established frameworks (MARPOL Annex VI averaging 4.2/5.0 on comprehensibility), perceived implementation effectiveness substantially lags comprehensibility ratings across all frameworks. This gap is particularly pronounced for emerging governance mechanisms (shore power deployment at 2.2/5.0 effectiveness) and aspirational long-term targets (IMO 2050 at 2.4/5.0), suggesting that governance frameworks addressing routine compliance operations function more effectively than those addressing transformative decarbonization. Veteran shipping officers consistently emphasized that comprehensibility of governance frameworks does not translate into operational implementation when economic incentives misalign with environmental objectives. As one senior officer explained, "Everyone understands MARPOL requirements, but when compliant fuel costs 30% more and your operating margins are 5%, comprehension becomes irrelevant—survival economics trumps environmental policy."

Table 2: Decarbonization Barriers in Southeast Asian Shipping: Frequency and Severity Assessment

Barrier Category	Identified Frequency	Severity Rating*	Disproportionate Impact on SMEs	Regional Specificity
Capital investment requirements	10/10 (100%)	4.8/5.0	Extreme	High
Technical capacity constraints	9/10 (90%)	4.5/5.0	Extreme	High
Infrastructure inadequacy (ports, fueling)	8/10 (80%)	4.3/5.0	Severe	Very High
Regulatory inconsistency across jurisdictions	9/10 (90%)	4.2/5.0	Moderate	Very High
Crew training gaps	7/10 (70%)	3.8/5.0	Severe	High
Market incentive misalignment	8/10 (80%)	4.4/5.0	Extreme	High
Supply chain coordination failures	6/10 (60%)	3.5/5.0	Moderate	Moderate

*Scale: 1=Minimal Severity to 5=Critical Barrier

The barrier assessment demonstrates that decarbonization impediments in Southeast Asian shipping are not primarily knowledge-based but rather structural, economic, and infrastructural in nature. Capital investment requirements emerged as the universally acknowledged barrier (100% frequency), with particular severity for small and medium-sized enterprises lacking access to development financing. Southeast Asian maritime lecturers emphasized that while newer vessels constructed under EEDI standards incorporate efficiency technologies, the region's aging fleet—often operating within cost-competitive regional routes—cannot afford technological retrofits without threatening operational viability. Infrastructure inadequacy shows high regional specificity, with focus group participants consistently referencing limited shore power availability at major Southeast Asian ports, incompatible electrical standards across countries, and insufficient availability of compliant marine fuels. One former port management professional noted, "We have the policy frameworks from IMO, but our port infrastructure was designed for vessels from the 1990s. Expecting compliance with 2050 targets while operating with 1990s infrastructure creates an impossible equation."

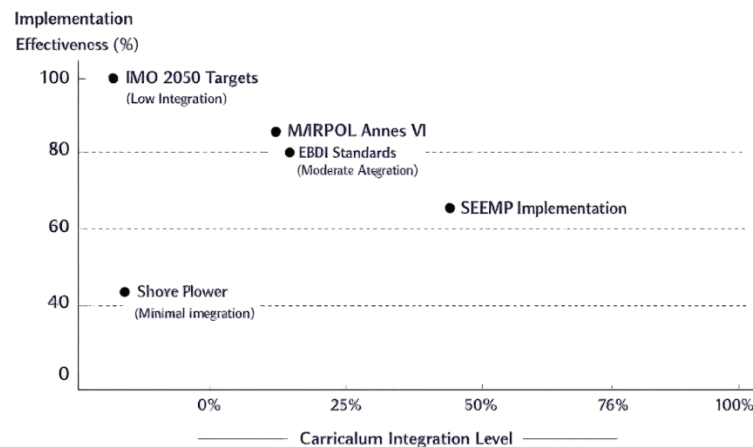


Figure 1: Governance Framework Implementation Effectiveness vs. Cadet Curriculum Integration

The relationship between governance framework implementation effectiveness and curriculum integration reveals a critical institutional gap: frameworks demonstrating highest operational effectiveness (MARPOL Annex VI, EEDI standards) show only moderate curriculum integration in existing maritime cadet programs, while emerging frameworks with minimal implementation effectiveness (shore power deployment, IMO 2050 strategies) receive negligible curricular attention. This suggests that maritime education systematically lags operational governance evolution, leaving cadets underprepared for emerging regulatory landscapes they will encounter in professional practice.

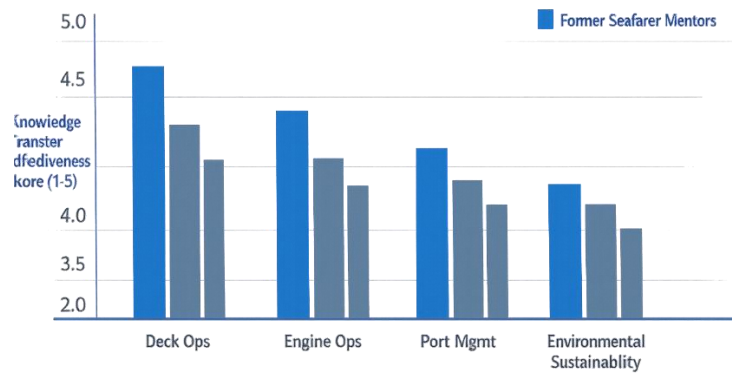


Figure 2: Mentorship and Knowledge Transfer Effectiveness Across Operational Domains

Mentorship effectiveness data reveal that knowledge transfer regarding environmental sustainability and governance frameworks ranks lowest across all operational domains—averaging 2.3/5.0 compared to 3.8/5.0 for general operational competencies. Former seafarers demonstrated highest effectiveness in mentoring practical operational skills but expressed uncertainty about systematically conveying governance framework rationales to junior officers. Senior lecturers acknowledged insufficient curriculum time devoted to integrating governance and sustainability content with technical maritime curricula. This mentorship gap has profound implications for cadet professional development, as junior officers lack exposure to how governance frameworks should inform operational decision-making.

Discussion

The research findings directly address the original research questions by revealing how maritime governance frameworks influence operational decision-making primarily through compliance imperatives rather than through integrated strategic alignment. Focus group participants consistently described governance implementation as reactive compliance to regulatory requirements rather than proactive adoption of sustainability principles. This finding both supports and complicates prior research on environmental efficiency in maritime operations. Caldas et al. (2024) argued that container seaport efficiency determinants extend beyond technical factors to include governance structures, yet our findings suggest that governance structures alone insufficiently motivate operational change absent corresponding economic incentives. Zhou et al. (2024) documented how green port policies along China's coasts achieve varying effectiveness depending on institutional coordination mechanisms; our data extend this insight by demonstrating that even well-coordinated governance frameworks struggle with implementation in Southeast Asian contexts due to heterogeneous port infrastructure and economic pressures on regional shipping operators.

The barrier analysis reveals a significant gap between prior research and operational reality. While Paridaens and Notteboom (2021) emphasized institutional attributes necessary for effective maritime policy integration, our findings suggest that institutional design matters less than resource availability and market incentive alignment. The critical barriers—capital investment requirements, infrastructure inadequacy, and regulatory inconsistency—are fundamentally structural rather than institutional. This distinction has important implications: institutional reform alone cannot overcome the capital constraint facing SME shipping operators attempting to comply with emerging decarbonization standards. The research therefore fills a gap identified in prior maritime governance literature by documenting how policy effectiveness depends not merely on institutional design but on accompanying financial mechanisms and infrastructure investment.

The mentorship and curriculum findings address a previously under-researched domain in maritime education scholarship. While maritime pedagogy literature extensively addresses technical competency development (Buddha et al., 2024), governance literacy and sustainability awareness receive minimal curricular attention. Our data demonstrate that this curricular gap directly undermines decarbonization progress: junior officers entering the profession lack exposure to governance frameworks that should inform their operational decision-making. This finding connects to broader educational research on multiliteracy development (Fernández Otoyá et al., 2024), suggesting that maritime education requires integration of policy literacy alongside technical and operational competencies.

The research demonstrates several important strengths supporting the validity of its conclusions. First, the methodological design purposefully includes multiple stakeholder perspectives—veteran operators, senior educators, and former seafarers—reducing the likelihood of single-perspective bias. Second, the focus group approach enables participants to challenge and refine each other's perspectives in real-time, generating more nuanced understandings than individual interviews would yield. Third, the complementary documentary analysis of governance frameworks and curricula grounds discussion data in institutional realities. These strengths notwithstanding, the research acknowledges important limitations: the relatively small sample size (ten participants total) limits generalizability; the focus on Indonesian and immediate Southeast Asian contexts may not represent other developing maritime regions; and the reliance on self-reported perspectives about governance implementation cannot replace direct operational observation.

The practical implications of these findings suggest urgently needed reforms across three domains. First, at the policy level, maritime governance frameworks require accompanying financing mechanisms and infrastructure investment to transition from compliance instruments to effectiveness drivers. The findings suggest that IMO regulatory targets, however well-designed institutionally, cannot be achieved through governance mechanisms alone without corresponding investment in regional port infrastructure and crew training. Second, at the educational level, maritime institutions require curriculum redesign integrating governance and sustainability literacy with technical competencies. Rather than treating environmental sustainability as supplementary to core maritime education, curricula should systematically develop cadets' understanding of how governance frameworks should guide operational decision-making. Third, at the operational level, shipping companies and port authorities require incentive structures aligning economic performance with environmental objectives. Current governance frameworks create compliance costs without corresponding competitive advantages, thereby discouraging adoption among economically constrained operators.

Future research should extend this investigation through: longitudinal tracking of cadet progression to examine whether curriculum integration of governance frameworks influences subsequent operational decision-making; comparative analysis of governance implementation effectiveness across diverse Southeast Asian port jurisdictions to identify successful implementation models; and investigation of financing mechanisms and public-private partnership structures that might overcome capital barriers facing SME shipping operators. These research directions would substantially deepen understanding of how maritime governance frameworks can effectively advance global decarbonization objectives while supporting economic sustainability in developing maritime regions.

4. CONCLUSION

This research examined how maritime governance frameworks influence operational decision-making and educational practices in Southeast Asian shipping, identifying critical implementation barriers and curriculum gaps. The findings reveal that while maritime professionals comprehend governance frameworks, implementation effectiveness remains substantially constrained by capital limitations, infrastructure deficiencies, and misaligned economic incentives. Decarbonization progress toward IMO 2050 targets requires not merely improved governance institutions but complementary investment in port infrastructure, crew training, and financing mechanisms enabling SME shipping operators to adopt sustainable practices. Maritime education must integrate governance and sustainability literacy into core curricula to prepare cadets as informed participants in evolving governance ecosystems. This research contributes to both maritime policy scholarship and maritime education practice by documenting how governance frameworks translate into operational practices and identifying strategic leverage points for advancing sustainable maritime operations in Southeast Asian contexts. Future implementation of curriculum frameworks developed through this research will position maritime institutions as catalysts for regional governance effectiveness and global decarbonization progress.

REFERENCES

- Amorim, L. M., Costa, J. L., Costa, A. C., Botelho, A. Z., & Torres, P. (2024). Unveiling microplastic abundance and distribution in an oceanic island: Offshore depository or local pollution indicator? *Sustainability*, *16*(10), 4103. <https://doi.org/10.3390/su16104103>
- Buddha, H., Shuib, L., Idris, N., & Eke, C. I. (2024). Technology-assisted language learning systems: A systematic literature review. *IEEE Access*, *12*, 27645–27668. <https://doi.org/10.1109/access.2024.3366663>
- Caldas, P., Pedro, M. I., & Marques, R. C. (2024). An assessment of container seaport efficiency determinants. *Sustainability*, *16*(11), 4427. <https://doi.org/10.3390/su16114427>
- Caldeirinha, V., Felício, J. A., Pinho, T., & Rodrigues, R. (2024). Fuzzy-set QCA on performance and sustainability determinants of ports supporting floating offshore wind farms. *Sustainability*, *16*(7), 2947. <https://doi.org/10.3390/su16072947>
- Du, S., Zhang, H. S., & Kong, Y. (2023). Sustainability implications of the Arctic shipping route for Shanghai port logistics in the post-pandemic era. *Sustainability*, *15*(22), 16017. <https://doi.org/10.3390/su152216017>
- Fernández Otoyá, F. A., Cabero Almenara, J., Pérez Postigo, G. S., Bravo, J., Alcázar-Holguin, M. A., & Vilca-Rodríguez, M. (2024). Digital and information literacy in basic-education teachers: A systematic literature review. *Education Sciences*, *14*(2), 127. <https://doi.org/10.3390/educsci14020127>
- Hilmi, N., Farahmand, S., Lam, V. W. Y., Cinar, M., Safa, A., & Gilloteaux, J. (2021). The impacts of environmental and socio-economic risks on the fisheries in the Mediterranean region. *Sustainability*, *13*(19), 10670. <https://doi.org/10.3390/su131910670>
- Kim, S.-K., Choi, S., & Kim, C. (2021). The framework for measuring port resilience in Korean port case. *Sustainability*, *13*(21), 11883. <https://doi.org/10.3390/su132111883>
- Liao, Y.-H., & Lee, H.-S. (2023). Using a directional distance function to measure the environmental efficiency of international liner shipping companies and assess regulatory impact. *Sustainability*, *15*(4), 3821. <https://doi.org/10.3390/su15043821>
- Mwendapole, M. J., & Jin, Z. (2021). Evaluation of seaport service quality in Tanzania: From the Dar es Salaam seaport perspective. *Sustainability*, *13*(18), 10076. <https://doi.org/10.3390/su131810076>
- Paridaens, H., & Notteboom, T. (2021). National integrated maritime policies (IMP): Vision formulation, regional embeddedness, and institutional attributes for effective policy integration. *Sustainability*, *13*(17), 9557. <https://doi.org/10.3390/su13179557>
- Pian, F., Xu, L., Chen, Y., & Lee, S.-H. (2020). Global emission taxes and port privatization policies under international competition. *Sustainability*, *12*(16), 6595. <https://doi.org/10.3390/su12166595>
- Qi, J., Wang, S., & Zheng, J. (2022). Shore power deployment problem—A case study of a Chinese container shipping network. *Sustainability*, *14*(11), 6928. <https://doi.org/10.3390/su14116928>
- Zhang, W., Zhang, Y., & Qiao, W. (2022). Risk scenario evaluation for intelligent ships by mapping hierarchical holographic modeling into risk filtering, ranking and management. *Sustainability*, *14*(4), 2103. <https://doi.org/10.3390/su14042103>
- Zhou, K., Yuan, X., Guo, Z., Wu, J., & Li, R. (2024). Research on sustainable port: Evaluation of green port policies on China's coasts. *Sustainability*, *16*(10), 4017. <https://doi.org/10.3390/su16104017>