INTERNATIONAL JOURNAL OF INDUSTRIAL MANAGEMENT
ISSN: 2289-9286 E-ISSN: 0127-564X
VOLUME 18, NO. 3, 2024, 166 – 172
DOI: https://doi.org/10.15282/ijim.18.3.2024.11215

RESEARCH ARTICLE

AN ASSESSMENT OF SUSTAINABLE DEVELOPMENT IN THE PORT INDUSTRY

Nguyen Tan Huynh

Department of Faculty of Economics-Management, Dong Nai Technology University, Bien Hoa, Vietnam

ABSTRACT - This research explores the multifaceted sustainability challenges and opportunities within the port sector. It employed Multiple-Criteria Decision-Making (MCDM) to evaluate and prioritise sustainability criteria that are critical to the port industry. Recognising the sector's significant economic contribution, the research emphasises the need for a balanced approach that integrates economic growth, environmental stewardship, and social responsibility. The findings provide a valuable framework for policymakers, port authorities, and industry stakeholders to implement sustainable practices that balance economic, environmental, and social objectives. The application of MCDM in this context demonstrates its effectiveness in addressing the complex sustainability challenges faced by the port industry.

ARTICLE HISTORY
Received : 01-03-2024
Revised : 01-06-2024
Accepted : 07-07-2024
Published : 10-09-2024

KEYWORDS
Social Responsibility
Port Industry
MCDM
Social
Economics
Environment

1. INTRODUCTION

The port industry is a vital component of global trade and logistics, playing an essential role in the economic development of countries. According to Makkawan and Muangpan (2021), ports serve as gateways for international trade by facilitating the import and export of goods and commodities. Container ports are hubs where maritime and land transport networks intersect (Hou & Geerlings, 2016), enabling the efficient transfer of cargo between ships and other modes of transportation like trucks and trains (Gharehgozli et al., 2017). Such connectivity supports global supply chains and ensures that products can reach markets promptly (Lu et al., 2016), ultimately driving economic growth and supporting livelihoods (Aregall et al., 2018). Moreover, hub ports are a critical infrastructure that supports various industries, including manufacturing (Du et al., 2019), agriculture, and retail (Aksoy & Durmusoglu, 2020). Boile et al. (2015) argued that ports enable industries to access raw materials and distribute finished products efficiently by providing the necessary facilities for the loading, unloading, storage, and distribution of goods. Such logistical support is crucial for maintaining the competitiveness of businesses and the broader economy (Lim et al., 2019; Sislian et al., 2016). Furthermore, ports are significant employers that generate jobs both directly within the port and indirectly through related industries, such as shipping, logistics, and warehousing (Ashrafi et al., 2020; Hossain et al., 2021). These employment opportunities subsequently contribute to the socioeconomic development of port cities and regions (Triska et al., 2024). However, the port industry also has significant environmental and social impacts. Ports are sources of pollution, including air emissions from ships (Nguyen et al., 2022) and cargo-handling equipment (Hsu & Huynh, 2023a), water pollution from discharges (Schipper et al., 2017), and noise pollution affecting nearby communities (Hsu et al., 2023). Additionally, the construction and expansion of port facilities can lead to habitat destruction and biodiversity loss (Makkawan & Muangpan, 2021). Socially, port activities can disrupt local communities, leading to issues like displacement (Hsu et al., 2022) and increased traffic congestion (Gharehgozli et al., 2017). These impacts highlight the importance of assessing sustainable development within the port industry to balance economic benefits with environmental protection and social well-being.

Sustainable development in the port industry involves adopting practices that can minimise environmental harm, promote social equity, and ensure long-term economic viability (Lirn et al., 2013; Munim et al., 2020). This includes implementing measures to reduce air and water pollution, such as using cleaner fuels and technologies (Hsu et al., 2021), enhancing waste management practices (Tseng & Pilcher, 2019), and protecting marine and coastal ecosystems (Hsu et al., 2024). Ports can also adopt energy-efficient infrastructure and renewable energy sources to reduce their carbon footprint (Chang & Wang, 2012). Sustainable development also involves engaging with local communities to address their concerns, create job opportunities, and enhance the quality of life (Hsu & Huynh, 2023b). Many prior studies demonstrate that assessing sustainable development in the port industry is crucial for several reasons. Firstly, it ensures that port operations do not compromise the health and well-being of local populations (Arof et al., 2021). According to Aksoy and Durmusoglu (2020), ports can reduce health risks associated with air and water pollution by monitoring and mitigating environmental impacts, ultimately contributing to healthier communities. Secondly, sustainable practices can enhance the resilience of ports to environmental changes, such as rising sea levels (Hsu et al., 2023) and extreme weather events (Lim et al., 2019), which are increasingly relevant due to climate change. Resilient ports can maintain their operations during disruptions, ensuring the continuity of global supply chains (Hsu et al., 2022; Hsu et al., 2024).

*CORRESPONDING AUTHOR | N.T. Huynh | ✉ huynhtannguyen@dntu.edu.vn

Furthermore, assessing sustainable development helps ports to comply with regulatory requirements and international standards (Tseng & Pilcher, 2019). Both governments and international organisations are increasingly implementing regulations to limit environmental impacts and promote sustainability (Lirn et al., 2013). By proactively adopting sustainable practices, ports can ensure compliance with these regulations, avoiding potential fines and legal issues (Frazzon et al., 2019). Additionally, sustainable development can enhance the reputation and competitiveness of ports. For instance, as consumers and businesses become more environmentally conscious, ports that demonstrate a commitment to sustainability can attract more clients and investors, thus gaining a competitive edge in the market (Aregall et al., 2018; Boile et al., 2015).

Incorporating sustainability into port operations also opens opportunities for innovation and efficiency. Sustainable practices often involve adopting new technologies and processes that can improve operational efficiency (Aksoy & Durmusoglu, 2020), reduce costs (Sislian et al., 2016), and enhance service quality (Shiau & Chuang, 2015). For example, the use of automation and digitalisation in port operations can streamline cargo handling (Hsu et al., 2023), reduce energy consumption (Du et al., 2019), and minimise errors (Bergqvist & Egels-Zandén, 2012). Such innovation can lead to long-term cost savings and improved performance, benefiting both the port and its clients. Moreover, assessing sustainable development in the port industry aligns with broader global efforts to achieve sustainable development goals (SDGs). Particularly, ports play a critical role in global trade (Gharehgozli et al., 2017) and their sustainable development can contribute to multiple SDGs, including those related to economic growth, industry innovation, climate action, and life below water (Lam & Notteboom, 2014; Triska et al., 2024). It is argued that ports can contribute to a more sustainable and equitable world by aligning their practices with these global goals (Aksoy & Durmusoglu, 2020). To fill the literature gap, this research aims to assess sustainable development in the port industry. It begins by investigating the criteria of sustainable development in the port industry before evaluating it using multiple-criteria decision-making (MCDM). The results hope to provide a methodological reference to the relevant literature.

2. LITERATURE REVIEW

Ensuring sustainable development in the port industry is crucial for long-term economic viability, environmental preservation, and social well-being. The development strategy is shaped by four main factors: Environmental Sustainability, Economic Growth, Social Sustainability, and Governance and Management. Each of these elements is crucial in influencing the practices and policies that ports implement to contribute to sustainable development. Environmental sustainability is a fundamental aspect of developing ports in a sustainable manner. Ports are major contributors to pollution, including air and water pollution (Chen et al., 2019), noise pollution (Nguyen et al., 2022), and habitat damage (Hsu et al., 2022). To tackle these problems, ports need to adopt extensive environmental management techniques (Makkawan & Muangpan, 2021). This involves mitigating air pollutants from ships and cargo-handling equipment through the implementation of cleaner fuels, electrification (Hou & Geerlings, 2016), and the utilisation of modern emission control systems (Gharehgozli et al., 2017). Ensuring the protection of water quality is of similar importance, encompassing strategies to prevent oil spills, regulate ballast water, and manage any discharge that resulted from port activities (Frazzon et al., 2019). Moreover, ports should prioritise energy efficiency by incorporating renewable energy sources like solar and wind power, as well as making investments in energy-efficient infrastructure and operations (Lim et al., 2019). Ports must also prioritise biodiversity protection by safeguarding and rejuvenating marine and coastal habitats impacted by their operations (Munim et al., 2020). By giving priority to environmental sustainability, ports can reduce their negative influence on the environment, protect natural resources, and support worldwide initiatives to address climate change (Shiau & Chuang, 2015).

The port industry relies heavily on economic growth, particularly as ports serve as crucial nodes in global trade and logistical networks. To achieve economic sustainability, it is necessary to improve operational efficiency by implementing automation (Gharehgozli et al., 2017), digitisation (Hou & Geerlings, 2016), and real-time data analytics for logistics management (Hsu & Huynh, 2023b). Investing in contemporary and durable infrastructure is crucial as it allows ports to efficiently manage growing cargo volumes and adjust to evolving market requirements (Hsu et al., 2023). Another crucial approach is economic diversification, which entails encouraging ports to facilitate a wide range of economic activity beyond the conventional domains of shipping and logistics. This can encompass supplementary services like transportation (Ashrafi et al., 2020), storage, and even leisure and tourism activities within port regions (Kuznetsov et al., 2015). Furthermore, it is imperative to guarantee the financial success of port operations by implementing effective financial management and making strategic investments. By prioritising economic growth, ports can maintain their competitiveness (Lu et al., 2016), generate employment opportunities (Makkawan & Muangpan, 2021), and bolster the overall economy, all while making a positive contribution to sustainable development (Hou & Geerlings, 2016).

Social sustainability pertains to the effects of port operations on nearby communities and labourers. Ports should proactively involve local communities in decision-making processes and address their concerns surrounding port activity (Hsu et al., 2021). Engaging in this process can foster confidence and guarantee that the expansion of the port brings advantages to the neighbouring communities. Ensuring health and safety is of utmost importance (Boile et al., 2015), necessitating ports to adopt rigorous health and safety protocols to safeguard workers and nearby communities from hazards linked to port activities (Arof et al., 2021). Furthermore, the creation of job opportunities and advocating for equitable labour practices are essential elements of social sustainability. Ports may bolster the local economy by generating employment, offering training and growth prospects, and guaranteeing equitable remuneration and working

conditions (Hsu & Huynh, 2023a). It is also imperative to safeguard cultural heritage due to the potential influence of port expansion on historical structures and cultural landscapes. Ports may enhance the cultural wealth of their regions by conserving these sites and fostering cultural events. Social sustainability aims to ensure that port activities do not have a negative impact, but instead contribute to improving the quality of life for local communities and workers (Du et al., 2019).

Effective governance and management are essential for the successful integration of sustainable practices into port operations. It entails maintaining adherence to local, national, and international standards pertaining to environmental preservation (Frazzon et al., 2019), safety, and labour practices (Lirn et al., 2013). Transparency and accountability are essential, necessitating ports to uphold transparent operations and be responsible to stakeholders. This can be accomplished by consistently reporting on sustainability performance and actively involving stakeholders in meaningful discussions (Chen et al., 2019). Stakeholder cooperation is a crucial element that promotes the formation of partnerships between government agencies, corporations, non-governmental organisations, and academic institutions (Hou & Geerlings, 2016). These collaborations aim to collectively achieve sustainable goals. Additionally, effective risk management is crucial and entails the identification and reduction of hazards linked to port operations, encompassing environmental, social, and economic issues. Ports may enhance their resilience and long-term profitability by implementing strong governance and management processes that prioritise sustainability in their strategic planning and daily operations (Hua et al., 2020; Kuznetsov et al., 2015).

Ultimately, sustainable development in the port industry is influenced by four primary factors: Environmental Sustainability, Economic Growth, Social Sustainability, and Governance and Management. Each of these variables is essential for influencing the practices and policies implemented by ports to contribute towards sustainable development. Ports can achieve a harmonious blend of economic development and sustainability by giving priority to environmental protection, fostering economic growth, ensuring social well-being, and adopting good governance methods. This comprehensive strategy guarantees that ports may function effectively and responsibly, making a positive contribution to the wider objectives of sustainable development and securing a more sustainable future for everyone.

3. DATA AND METHODOLOGY

This study conducted the MCDM approach via six primary steps, as follows:

First, the reciprocal positive matrix is defined by expert judgment by assuming that *a* is the rating of i over j. The value is defined as:

$$a_{ij} = \begin{cases} a_{ij}, & \text{if } i > j \\ 1, & \text{if } i = j \\ 1/a_{ji}, & \text{if } i < j \end{cases} \tag{1}$$

Subsequently, the reciprocal positive matrix can be found as:

$$A = [a_{ij}]_{n \times n} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & & \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \tag{2}$$

The second step is integrating expert ratings. The h expert in the sample can be used to create h reciprocal positive matrixes. Such ratings can be combined as follows (Nguyen et al., 2022):

$$a_{ij} = \left[\prod_{k=1}^{h} a_{ij}^{k} \right]^{\frac{1}{h}} \tag{3}$$

The third step involves figuring out the relative priority weight of ___. This is done using the NGMR technique developed by Saaty (2008). Call be the expected weight. Then, the relative priority weight is determined by:

$$W_i = \left(\prod_{j=1}^{m} a_{ij} \right)^{1/m} \Big/ \sum_{i}^{m} \left(\prod_{j=1}^{m} a_{ij} \right)^{1/m} \tag{4}$$

The fourth step is normalising the relative priority weight of $A = [a_{ij}]_{n \times n}$.

$$\omega_i = \frac{W_i}{\sum_{i=1}^{n} W_i} \times 100(\%) \tag{5}$$

The fifth step is determining the maximum eigenvalue (named) of Suppose according to the matrix theory. Then, we can get: Next, assume, can be found by:

$$\lambda_{\max} = \frac{1}{n}\left(\frac{W_1^{'}}{W_1} + \frac{W_2^{'}}{W_2} + ... + \frac{W_n^{'}}{W_n}\right) \quad (6)$$

Lastly, the CI and CR are adopted to check the consistency of expert ratings (Saaty, 2008):

$$CI = \frac{\lambda max - n}{n - 1} \quad (7)$$

and

$$CR = \frac{CI}{RI} \times 100(\%) \quad (8)$$

Saaty (2008) argued that illustrates the consistency of $A = [a_{ij}]_{n \times n}$

4. RESULTS AND DISCUSSION

4.1. Factors and Criteria

Table 1 shows the factors and criteria for assessing sustainable development in the port industry.

Table 1. Hierarchy of factors and criteria

Factors	Assessment Criteria	Code	Explanation
Environmental Sustainability (ES)	Air Quality Management	ES1	Implementing measures to reduce air pollutants from port operations, such as emissions from ships and cargo-handling equipment.
	Water Quality Protection	ES2	Preventing water pollution through proper waste management and controlling runoff and discharges from port activities.
	Energy Efficiency	ES3	Using energy-efficient technologies and renewable energy sources to reduce the carbon footprint of port operations.
	Biodiversity Conservation	ES4	Protecting and restoring natural habitats and ecosystems affected by port development and operations.
Economic Growth (EG)	Operational Efficiency	EG1	Improving the efficiency of port operations to reduce costs and enhance service quality, such as through automation and digitalisation.
	Infrastructure Investment	EG2	Investing in modern, resilient infrastructure that supports long-term economic growth and adapts to changing market demands.
	Economic Diversification	EG3	Encouraging diverse economic activities within and around ports to reduce dependency on a single industry and enhance economic stability.
	Financial Performance	EG4	Ensuring the financial health of port operations through sound financial management and strategic investments.
Social Sustainability (SS)	Community Engagement	SS1	Actively involving local communities in decision-making processes and addressing their concerns regarding port operations.
	Health and Safety	SS2	Implementing stringent health and safety measures to protect workers and local populations from risks associated with port activities.
	Employment Opportunities	SS3	Creating jobs and promoting fair labour practices to support the local economy and improve livelihoods.
	Cultural Heritage Protection	SS4	Preserving cultural and historical sites that may be impacted by port development and operations.
Governance and Management (GM)	Regulatory Compliance	GM1	Ensuring adherence to local, national, and international regulations and standards related to environmental protection, safety, and labour practices.
	Transparency and Accountability	GM2	Maintaining transparent operations and being accountable to stakeholders, including regular reporting on sustainability performance.
	Stakeholder Collaboration	GM3	Fostering collaboration among various stakeholders, including government agencies, businesses, and non-governmental organisations, to achieve shared sustainability goals.
	Risk Management	GM4	Identifying and managing risks associated with port operations, including environmental, social, and economic risks.

4.2. Relative Weightage of the Factors and Criteria

Table 2 shows the relative weightage of the factors and criteria for assessing sustainable development in the port industry.

Table 2. Relative weightage of factors and criteria

Factors	Global Weight (%)	Criteria	Local Weight (%)	Global Weight (%)
Environmental Sustainability (ES)	17.64	ES1	15.63	2.76
		ES2	21.98	3.88
		ES3	23.83	4.20
		ES4	38.56	6.80
Economic Growth (EG)	22.07	EG1	29.54	6.52
		EG2	28.11	6.20
		EG3	19.59	4.32
		EG4	22.76	5.02
Social Sustainability (SS)	28.63	SS1	17.14	4.91
		SS2	27.59	7.90
		SS3	29.77	8.52
		SS4	25.49	7.30
Governance and Management (GM)	31.66	GM1	19.83	6.28
		GM2	18.18	5.76
		GM3	29.53	9.35
		GM4	32.46	10.28

4.3. Discussion

The empirical results illustrate that the top five criteria for establishing sustainable development in the port industry include Risk Management (10.28%), Stakeholder Collaboration (9.35%), Employment Opportunities (8.52%), Health and Safety (7.90%), and Cultural Heritage Protection (7.30%). Makkawan and Muangpan (2021) pointed out that ports must adapt quickly to climate change and the evolving global trade dynamics. Thus, risk management frameworks provide the flexibility to adjust strategies in response to emerging threats and opportunities. Besides, collaborative efforts can build trust among stakeholders, thus fostering a supportive environment for port projects. This is particularly important for gaining community support and avoiding conflicts. Moreover, providing stable and fair employment opportunities reduces social tensions and contributes to the social fabric of the port communities, which helps to create a positive perception of port activities among locals (Frazzon et al., 2019; Gharehgozli et al., 2017). Boile et al. (2015) demonstrated that the port environment can be hazardous; thus, prioritising health and safety will ensure the well-being of workers and reduce the incidence of accidents and occupational illnesses. Integrating cultural heritage protection into port development also aligns with broader sustainability goals, ensuring that economic development does not come at the expense of cultural assets.

In summary, the emphasis on these five criteria reflects a comprehensive approach to sustainable development in the port industry. Risk management ensures resilience; stakeholder collaboration fosters inclusive and innovative solutions; employment opportunities drive economic and social benefits; health and safety protect workers and ensure efficient operations; and cultural heritage protection preserves the identity and history of port areas, ultimately contributing to broader sustainability goals. These criteria collectively ensure that ports can grow and develop sustainably, balancing economic needs with social and environmental responsibilities.

5. CONCLUSION

The port industry plays a pivotal role in the global economy by facilitating international trade and contributing significantly to economic growth. However, this sector also faces substantial environmental and social challenges that necessitate a comprehensive approach to sustainable development. This research aims to evaluate the sustainability practices within the port industry through the lens of Multiple-Criteria Decision-Making (MCDM). By integrating various sustainability criteria, this study provides a holistic view of the efforts required to balance economic development, environmental protection, and social responsibility in port operations. The findings indicate that sustainable development in the port industry is progressing, albeit at varying rates across different regions and ports. Ports that have adopted advanced technologies and innovative practices demonstrate notable improvements in reducing emissions, enhancing energy efficiency, and minimising waste. These ports serve as benchmarks for others aiming to achieve similar sustainable development goals. The adoption of green technologies, such as electrification of port equipment, use of renewable energy

sources, and implementation of advanced waste management systems, has proven effective in mitigating environmental impacts.

However, the assessment also revealed several challenges that hinder the widespread adoption of sustainable practices. Financial constraints, lack of regulatory harmonisation, and the need for substantial initial investments pose significant barriers. Moreover, the varying levels of technological advancement and infrastructure development among ports contribute to the uneven implementation of sustainable practices. Smaller ports, in particular, face difficulties in accessing the necessary resources and expertise to implement green technologies and practices. Despite receiving increasing attention, social sustainability remains an area that requires further development. Ports must strengthen their engagement with local communities to ensure that development projects do not adversely affect the livelihoods and well-being of surrounding populations. Initiatives such as community outreach programs, stakeholder consultations, and transparent communication strategies are essential for fostering positive relationships and promoting social equity.

The findings of this research highlight the importance of adopting a multifaceted approach to sustainability. The top five criteria identified for sustainable development in the port industry-Risk Management, Stakeholder Collaboration, Employment Opportunities, Health and Safety, and Cultural Heritage Protection-underscore the diverse aspects that must be considered. These criteria reflect the complex interplay between economic, environmental, and social dimensions of sustainability, each contributing uniquely to the overall sustainability goals. The application of Multiple-Criteria Decision-Making in assessing sustainable development in the port industry provides a comprehensive framework for evaluating and prioritising various sustainability criteria. Furthermore, this study highlights the importance of a balanced approach that integrates economic growth, environmental stewardship, and social responsibility. Ports must adopt holistic sustainability strategies to address the diverse challenges and opportunities identified in this research, which will enhance their resilience, foster community support, and contribute to the broader goals of sustainable development. Insights from this study also provide valuable guidance for policymakers, port authorities, and industry stakeholders to promote sustainable practices and achieve long-term success in the port industry.

ACKNOWLEDGEMENT

The authors would like to thank Dong Nai Technology University, Dong Nai, Vietnam for the support.

CONFLICT OF INTEREST

The author declares no conflicts of interest.

AUTHORS CONTRIBUTION

The author fully prepared the manuscript, including the research, drafting, revising, and finalising the content.

REFERENCES

Aksoy, S., & Durmusoglu, Y. (2020). Improving competitiveness level of Turkish intermodal ports in the Frame of Green Port Concept: A case study. Maritime Policy & Management, 47(2), 203-220.

Aregall, M. G., Bergqvist, R., & Monios, J. (2018). A global review of the hinterland dimension of green port strategies. Transportation Research Part D: Transport and Environment, 59, 23-34.

Arof, A. M., Zakaria, A., & Rahman, N. S. F. A. (2021). Green port indicators: A review. Advanced Engineering for Processes and Technologies II, 237-256.

Ashrafi, M., Walker, T. R., Magnan, G. M., Adams, M., & Acciaro, M. (2020). A review of corporate sustainability drivers in maritime ports: a multi-stakeholder perspective. Maritime Policy & Management, 47(8), 1027-1044.

Bergqvist, R., & Egels-Zandén, N. (2012). Green port dues-The case of hinterland transport. Research in Transportation Business & Management, 5, 85-91.

Boile, M., Theofanis, S., & Baveja, A. (2015). An integrative conceptual framework for stakeholder collaboration in maximizing port industry performance–The case of the NY/NJ Region. In Proceedings of the 47th Annual Transportation Research Forum.

Chang, C.-C., & Wang, C.-M. (2012). Evaluating the effects of green port policy: Case study of Kaohsiung harbor in Taiwan. Transportation Research Part D: Transport and Environment, 17(3), 185-189.

Chen, J., Zheng, T., Garg, A., Xu, L., Li, S., & Fei, Y. (2019). Alternative maritime power application as a green port strategy: Barriers in China. Journal of Cleaner Production, 213, 825-837.

Du, K., Monios, J., & Wang, Y. (2019). Chapter 11 - Green Port Strategies in China. In Green ports, Elsevier, 211-229.

Frazzon, E. M., Constante, J. M., Triska, Y., Albuquerque, J. V. D. S., Martinez-Moya, J., Silva, L. D. S., & Valente, A. M. (2019). Smart port-hinterland integration: Conceptual proposal and simulation-based analysis in Brazilian ports. International Journal of Integrated Supply Management, 12(4), 334-352.

Gharehgozli, A. H., Mileski, J., Adams, A., & von Zharen, W. (2017). Evaluating a "wicked problem": A conceptual framework on seaport resiliency in the event of weather disruptions. Technological Forecasting and Social Change, 121, 65-75.

Hossain, T., Adams, M., & Walker, T. R. (2021). Role of sustainability in global seaports. Ocean & Coastal Management, 202, 105435.

Hou, L., & Geerlings, H. (2016). Dynamics in sustainable port and hinterland operations: A conceptual framework and simulation of sustainability measures and their effectiveness, based on an application to the Port of Shanghai. Journal of Cleaner Production, 135, 449-456.

Hsu, W.-K., Huang, S.-H., & Huynh, T. N. (2021). An evaluation model for foreign direct investment performance of free trade port zones. Promet-Traffic&Transportation, 33(6), 859-870.

Hsu, W.-K., & Huynh, N. T. (2023a). Container terminals' efficiency with the unexpected output: A revised SBM approach. Environmental Science and Pollution Research, 30(13), 37845-37858.

Hsu, W.-K., & Huynh, N. T. (2023b). An evaluation of productive efficiency for container terminals affiliated to a single organisation. Journal of Transport Economics and Policy (JTEP), 57(1), 59-76.

Hsu, W.-K., Wei, Y.-C., Lee, C.-H., Hoang, L. V., & Huynh, N. T. (2023). A risk assessment model of work safety in container dry ports. Proceedings of the Institution of Civil Engineers-Maritime Engineering, 176 (4), 193-205.

Hsu, W.-K. K., Huang, S.-H. S., & Huynh, N. T. (2023). An assessment of operating efficiency for container terminals in a port–An empirical study in Kaohsiung Port using Data Envelopment Analysis. Research in Transportation Business & Management, 46, 100823.

Hsu, W.-K. K., Tai, H.-H., Tan Huynh, N., & Chen, J.-W. C. (2022). Assessing the investment environment in container terminals: A knowledge gap model. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 236(3), 585-599.

Hsu, W. K. K., Huang, S. H. S., Huynh, N. T., & Huang, K. H. (2024). An evaluation model of sustainable efficiency for container terminals. Sustainable Development, 32(1), 1170-1187.

Hua, C., Chen, J., Wan, Z., Xu, L., Bai, Y., Zheng, T., & Fei, Y. (2020). Evaluation and governance of green development practice of port: A sea port case of China. Journal of Cleaner Production, 249, 119434.

Kuznetsov, A., Dinwoodie, J., Gibbs, D., Sansom, M., & Knowles, H. (2015). Towards a sustainability management system for smaller ports. Marine Policy, 54, 59-68.

Lam, J. S. L., & Notteboom, T. (2014). The greening of ports: a comparison of port management tools used by leading ports in Asia and Europe. Transport Reviews, 34(2), 169-189.

Lim, S., Pettit, S., Abouarghoub, W., & Beresford, A. (2019). Port sustainability and performance: A systematic literature review. Transportation Research Part D: Transport and Environment, 72, 47-64.

Lirn, T. c., Jim Wu, Y. C., & Chen, Y. J. (2013). Green performance criteria for sustainable ports in Asia. International Journal of Physical Distribution & Logistics Management, 43(5/6), 427-451.

Lu, C.-S., Shang, K.-C., & Lin, C.-C. (2016). Examining sustainability performance at ports: port managers' perspectives on developing sustainable supply chains. Maritime Policy & Management, 43(8), 909-927.

Makkawan, K., & Muangpan, T. (2021). A conceptual model of smart port performance and smart port indicators in Thailand. Journal of International Logistics and Trade, 19(3), 133-146.

Munim, Z. H., Sornn-Friese, H., & Dushenko, M. (2020). Identifying the appropriate governance model for green port management: Applying Analytic Network Process and Best-Worst methods to ports in the Indian Ocean Rim. Journal of Cleaner Production, 268, 122156.

Nguyen, T. Q., Ngo, L. T. T., Huynh, N. T., Quoc, T. L., & Hoang, L. V. (2022). Assessing port service quality: An application of the extension fuzzy AHP and importance-performance analysis. PloS one, 17(2), e0264590.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. International Journal of Services Sciences, 1(1), 83-98.

Schipper, C., Vreugdenhil, H., & De Jong, M. (2017). A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements. Transportation Research Part D: Transport and Environment, 57, 84-111.

Shiau, T.-A., & Chuang, C.-C. (2015). Social construction of port sustainability indicators: A case study of Keelung Port. Maritime Policy & Management, 42(1), 26-42.

Sislian, L., Jaegler, A., & Cariou, P. (2016). A literature review on port sustainability and ocean's carrier network problem. Research in Transportation Business & Management, 19, 19-26.

Triska, Y., Frazzon, E. M., Silva, V. M. D., & Heilig, L. (2024). Smart port terminals: conceptual framework, maturity modeling and research agenda. Maritime Policy & Management, 51(2), 259-282.

Tseng, P.-H., & Pilcher, N. (2019). Evaluating the key factors of green port policies in Taiwan through quantitative and qualitative approaches. Transport Policy, 82, 127-137.