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Acceleration of Green Transitions on the Base of Port Organizational Ecosystem's Resilience Enhancement: A Socio-Technological Approach

Elena Valioniene [1,*], Erika Zuperkiene [1] and Birute Placiene [2]

[1] Management Department, Faculty of Social Sciences and Humanities, Klaipeda University, Salomejos Neries Str. 5, 92227 Klaipeda, Lithuania; erika.zuperkiene@ku.lt
[2] Department of Marine Engineering, Faculty of Marine Technologies and Natural Sciences, Klaipeda University, Bijunu Str. 17, 91225 Klaipeda, Lithuania; birute.placiene@ku.lt
* Correspondence: elena.valioniene@ku.lt

Abstract: Seaports are pivotal nodes in global trade, under increasing pressure to expedite green transitions while navigating the complexities of modern economic and environmental challenges. This research investigates the intricate relationship between the resilience of port organizational ecosystems and the successful implementation of green transitions. Employing a combination of focus group interviews and participatory observation, the study explores the primary obstacles, particularly the insufficiency of managerial capacity, which hampers the integration of technological innovations. Challenges identified include outdated infrastructure, cybersecurity vulnerabilities, and the imperative for sustained investment in new technologies, along with the need to promote a culture of sustainability. Experts highlight the crucial role of managerial competencies and continuous learning in overcoming these barriers. Furthermore, the research underscores the importance of fostering strong partnerships among stakeholders, including government bodies, industry associations, and environmental organizations. The findings offer valuable insights for policymakers, port managers, and other stakeholders seeking to navigate the challenges for ensuring a sustainable future for the maritime sport organizational ecosystems and maritime industry.

Keywords: port organizational ecosystem's resilience; green transitions; management skills

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1. Introduction

As global trade faces unprecedented challenges such as climate change, economic volatility, and evolving regulatory standards, the resilience of seaports and port organizational ecosystems (POEs) has become crucial for maintaining the stability and sustainability of ports and supply chains. Numerous studies have identified key obstacles in the transition to greener port operations, including outdated infrastructure [1], digitization and cybersecurity risks [2], and a lack of strategic managerial competencies [3,4]. For instance, the International Maritime Organization (IMO) has emphasized the need for ports to align operations with global greenhouse gas reduction goals, urging the adoption of low-emission technologies and practices [5]. Furthermore, digitization is seen as a pivotal force for improving resilience and sustainability in POEs, with digital technologies and automation driving greener operations [2,6–8].

Green transitions refer to the systematic changes that ports implement to reduce their environmental impacts, primarily by adopting sustainable technologies and practices [4,9]. This concept is closely tied to the guidelines and reports developed by various organizations aiming to promote sustainability in port operations. The European Commission's actions for reducing emissions from shipping [10] encourage sustainable practices and eco-friendly maritime transportations to meet both environmental and economic goals, pushing shipping processes toward innovation in energy use and resource management [3,9]. Similarly,

shipping, port operations, and other port-related activities have become the statistical object from the perspectives of green ports and different measures of this criteria, as greenhouse gas emissions are analyzed and presented in the newest reports [6,11]. In the realm of risk management, ports require robust strategies to reduce potential threats. The United Nations published the 2030 agenda for sustainable development [12], wherein the main transitions for sustainability can be found and the main sustainable goals are also identified [8,13]. Deeper analysis of interactive sources for the implementation of sustainable actions and for maintaining the resiliency of ports under the influence of uncertainties and under the influence of new engineering technologies implementing green transition processes can be found in the guidelines for ports, including how to build capacity to manage risks and enhance resilience [14], how to enhance resilience during green transitions [15], and how to accelerate processes [16]. But as research [17–19] has shown, the green transitions in POEs are not very intensive; even digitization and other automation processes increase in their implementation actions. So, the main question is what ways to improve and fasten green transitions in the whole POE and provide more port operations that are friendly to the environment and urbanized areas around the ports through sustainable innovations and high resilience.

The research object is the resilience of POEs as the attribute for the acceleration of green transitions, and the main aim is to investigate how to accelerate green transitions in POEs in the conditions of their resilience enhancement for moving toward more sustainable coastal regions. The objectives of research are to briefly describe the reasons and conditions for the green transitions in ports, implement empirical research for the identification of the main challenges for POE resilience, and to find possible managerial interventions for the enhancement of resilience and fastening green transitions in ports. By addressing these objectives, this study aims to deliver valuable insights that can assist port authorities and stakeholders in navigating the complexities of technological integration to enhance resilience and promote sustainability. In alignment with the research objectives, the specific hypothesis can be articulated as follows: The integration of advanced technological innovations and adaptive management practices is expected to accelerate green transitions within POEs through the implementation of targeted managerial interventions. In accordance with the defined objectives, the methodology of this research is complex and consists of literature analysis and qualitative empirical research wherein deep content analysis methodology and some visualization techniques such as word clouds and relationship diagrams are also applied.

Ultimately, the findings of this research contribute to a deeper understanding of how ports can adapt to environmental demands while strengthening their operational efficiencies through green transitions and strengthening managerial skills through understanding the factors stopping these transitions.

2. Materials and Methods

Since this research aims to identify the key connections between the resilience of POEs and managerial actions related to green transitions, a previously established theoretical model that outlines resilience and highlights external factors that negatively affect it was used [20,21]. While green transitions serve as a latent variable within this model, they can both disrupt the balance and enhance the resilience of POEs [7,22]. These transitions involve various engineering innovations that push the maritime industry toward greater sustainability, such as autonomous shipping, which improves navigation and safety; green technologies like hybrid and liquefied natural gas (LNG) engines; advanced materials that promote fuel efficiency; and digitalization through Internet of Things (IoT) devices for real-time operational monitoring and predictive maintenance. Furthermore, innovations in navigation systems, energy storage, port automation, and cybersecurity support cleaner operations [23], including strategical decisions on reducing energy consumption through applying an innovative technological behavioral system for transport flows [24]. While these advancements contribute significantly to reducing emissions and promoting sus-

tainable practices [23], effective implementation is often challenged by human behavioral risks [25]. The success of green transitions relies heavily on flexible decision-making and leadership types [26], enabling ports to adapt to new technologies and foster a culture of sustainability [21,27]. To address the challenges within the POE and improve its resilience while promoting green transitions, it is essential to explore effective managerial interventions. This is particularly important due to the absence of comprehensive assessment systems for monitoring the progress of green ports and transitions, as the triple-bottom-line approach to sustainability is inadequate for capturing the full complexity of green transition advancements. Despite the growing importance of environmental performance in port operations, there is a notable absence of standardized tools and methodologies to quantify and track green transitions [28–31]. This gap not only complicates efforts to evaluate progress, but also limits the ability to set actionable sustainability targets.

The complexity of green port development—demanding integrated resource management, multi-objective decision-making, and consideration of hinterland connectivity—requires sophisticated approaches beyond traditional economic models [28]. Therefore, developing a structured system of managerial interventions is vital for addressing systemic barriers, optimizing resource allocation, fostering collaboration, and effectively measuring progress toward sustainability goals [32,33]. Such a framework is essential for navigating the complexities of green transitions and achieving both resilience and accelerated progress.

This research employs a combined methodology of focus group interviews and participatory observation. Focus groups facilitate group discussions aimed at identifying perceptions, thoughts, and impressions of selected participants regarding a particular research topic. It is crucial that participants perceive these discussions as non-threatening, encouraging them to express any opinion freely, whether or not it is shared by other participants. Focus group discussions gathered insights from participants about the research topic, providing valuable perspectives often overlooked in quantitative studies [34]. Participatory observation allowed the researcher to engage with stakeholders during various conferences and sessions, gaining first-hand insights and a deeper understanding of the subject [35]. Two focus groups were formed to encompass diverse stakeholders in the maritime field. The first group included experts from the maritime industry in Lithuania, while the second group comprised international experts from countries such as France, Slovenia, Germany, Latvia, Estonia, and Poland. A total of 11 experts participated in each focus group, and an additional 15 responses were obtained through participatory observation. This approach ensured representation from multiple shipping regions, including the Baltic Sea, Atlantic Ocean, North Sea, and Adriatic Sea, thereby capturing diverse climatic and geographical conditions. However, it is important to note that the primary focus of this research was on managerial problem-solving, which is typically less sensitive to climatic and geographical factors, but more influenced by port size. Consequently, experts were selected from medium-sized ports, such as the Port of Klaipeda, as port size plays a critical role in shaping the functions and roles within the organizational ecosystem.

For the participant selection process, a combination of purposeful sampling and stratified sampling was used. Purposeful sampling [36] was used for the selection of participants who could be deliberately chosen for their expertise and relevance to the research from specific countries. Stratified sampling [36] was used for the representation of different groups within the POE, such as primary port service providers, management companies, government and non-government organizations, and others. According to the methodology of stratified sampling of the structure of POE stakeholders, each expert focus group comprised key stakeholders from the POE. Previous research [37–39] identified the typical stakeholder distribution as follows: primary port service and operations providers—44%; management companies and organizations—15%; governmental and non-governmental organizations—15%; hinterland logistics service providers and other entities invested in supply chain connectivity through maritime transport—15%; and scientists and researchers—1%. Reflecting the described stakeholder structure, the selected proportion closely aligned, with most experts coming from primary port activity sectors.

In the port governance domain, experts were chosen from various governance structures: a state-owned limited company in Klaipeda, a municipally owned limited company in Koper, and a consortium of three ports in France managed by the state-owned limited liability company Haropa. It is noteworthy that, considering the inclusion of Klaipeda, a middle-sized seaport, the research also engaged other port authorities from middle-sized or smaller ports due to their complex investment scenarios and ecosystem resilience challenges, as identified in previous studies [13,40–42]. The biggest stakeholder group consisted of five experts in each group. The Lithuania expert group included representatives from Lithuanian stevedoring company associations, shipowners' associations, and agents' and forwarders' associations, as well as representatives of the biggest port warehouses' services providers and container terminals (codes S1EL1, . . ., S1EL5). The international group included representatives of the Central Association of Germany Port Operators, the Gdansk port container terminal, the Association of Polish Maritime Industries, the Estonian Logistics and Freight Forwarding Association, and the Latvian Ship Suppliers Association (codes S1EI1, . . ., S1EI5). Experts from other types of stakeholders were also invited: representatives of the Lithuanian Transport Safety Administration and towage services providing company (codes S3EL8, S3EL9), of the Slovenian Maritime Administration, of the German Federal Maritime and Hydrographic Agency (codes S3EI8, S3EI9), of the Lithuanian National Road Carriers' Association "LINAVA" (code S4EL10), and of the German Port Technology Association (code S4EI10), as well as a Klaipeda University researcher (code S5EL11) and a researcher from the University of Normandy in Le Havre (code S5EI11).

The structured agenda addresses the challenges of enhancing resilience within the POE and their manageability. The main questions guiding the agenda are as follows.

1. What challenges within the POE resilience framework can be identified, and what are their factors and impacts?
2. What managerial interventions can be utilized to withstand external uncertainties affecting the POE, and how can these interventions be managed?

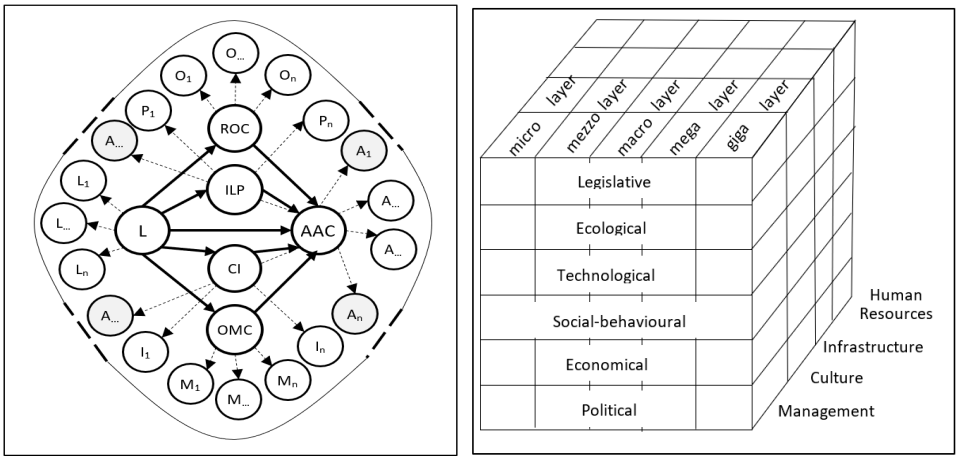
As could be seen in the agenda of focus group discussions, the primary focus of the study did not revolve around green transitions; but in the context of the discussions, the definition of green transition appeared to be the technological challenge for POE and an effective working tool for the POE's resilience, and the research on green transitions could be implemented as mentioned in previously analyzed literature [10–12].

Data collection was conducted through remote meetings using Zoom, facilitated by an international group using NVivo 14 software, with a semi-structured discussion guide. A moderator facilitated the discussions, encouraged participation, and ensured that all relevant topics from the structured agenda were covered. The data collected provided rich qualitative information for subsequent analysis, and all data are accessible through request to the correspondent author of this research.

Thematic analysis was employed for the analysis of the focus group data and data obtained during participatory observation. Transcripts were coded according to stakeholders' functional and international types. Deep content analysis was oriented to the classification of different challenges according to two classification models. One of them is based on the assessment framework for external environmental factors [35], distributing uncertainties in different domains of the different globalization levels (Figure 1b).

The second one is based on the definition of POE resilience [13], which mentions that POE resilience is the organizational ecosystem's capacity to absorb shocks, adapt to change, and maintain essential functions in the face of unforeseen events, driven by strong leadership and the ecosystem's inherent ability to learn and evolve. It is not merely the sum of individual organizations' resilience, but a complex system property that requires holistic analysis and management strategies. As such, the definition includes the four main components of organizational resilience, focusing on internal aspects of the POE (Figure 1a): the critical infrastructure component (CI); human resources challenges (ILPs); management skills (OMCs); and organizational culture (ROC) [13]. And all these components have to be

managed by flexible leadership (L) principles and decision-making for the improvement of adaptive capacity (AAC) in the whole ecosystem for keeping high resilience under the influence of uncertainties (Figure 1a).



(**a**) (**b**)

Figure 1. Theoretical model of POE resilience (**a**) [13] and for the uncertainties classified in the theoretical model (**b**) [13,14].

These classifications add an aim to identify possible relationships between different categories of challenges for POE resilience and to find some answers about the possible effective managerial interventions required for the enhancement of POE resilience and acceleration of green transitions.

For analysis and visualization, the research employed word cloud methodology and cross-content analysis to identify relationships among the different types of challenges.

The word cloud method in qualitative analysis visually presents the most important terms from focus group discussions, allowing for an analysis of various attributes and categories related to the challenges. Before applying the word cloud technique, a detailed categorization and classification of the identified challenges was conducted and primary text data were cleaned, removing common stop words and irrelevant content. After uploading to the specialized Word Cloud software (https://www.mentimeter.com, accessed on 24 October 2024), the frequently occurring words appear larger, giving a quick and intuitive sense of prominent themes and topics.

Cross-content analysis can involve comparing different classification and categorization schemes to assess how various frameworks organize the data, potentially revealing different insights or perspectives. This approach allows researchers to identify the most effective ways to categorize data, highlight unique patterns, and gain a broader understanding of the themes. Cross-content analysis enables the identification of key relationships between different challenges in POEs and highlights the main drivers for accelerating green transitions. The synthesis of these analyses helps draw meaningful conclusions relevant to the research goals. Descriptive statistics were used to calculate the frequency of various challenges, helping to determine fields for improvement.

The research design utilized purposeful and stratified sampling to enhance validity and reliability. Participants were required to have at least five years of managerial experience and specific expertise relevant to their stakeholder type. This careful selection ensured rich and relevant data, while stratification provided the systematic representation of all key groups involved. The validity of the conclusions was further strengthened through cross-verification and comparing answers across different fields. Additionally, remote discussions were held to gather feedback on the overall conclusions. In line with open data science principles, all research data can be shared upon request.

3. Results

The analysis of expert responses regarding the challenges faced by POEs indicates that most identified impediments are technological in nature (Figure 2a). A smaller portion of challenges relates to economic and environmental factors that affect the operational dynamics of the seaport ecosystem under uncertain conditions. The analysis of experts' opinions reveals that technological challenges could possibly be linked to management skills (Figure 2b). It is hypothesized that the technological challenges confronting POEs are closely related to managerial skills in technological innovation practices.

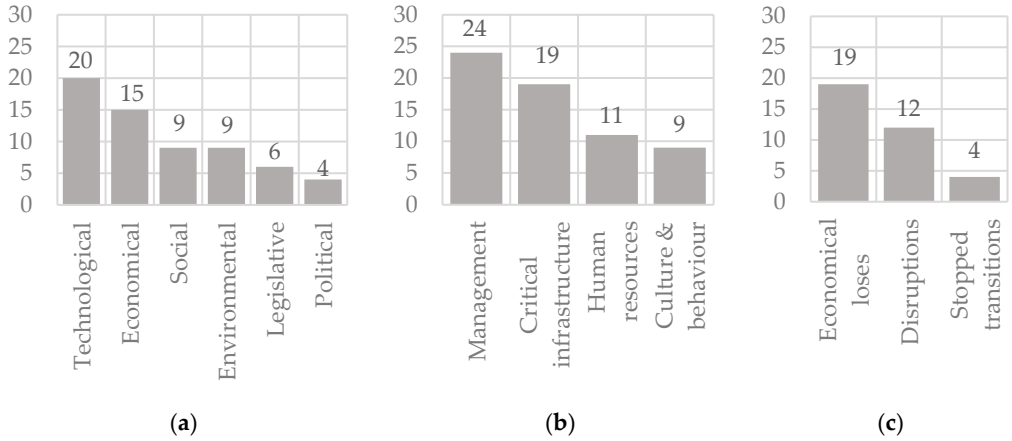


Figure 2. Frequencies of challenges (**a**,**b**) and impacts (**c**) according to the results of focus group discussion: (**a**) classification by political, economic, social, environmental, and legislative factorial field; (**b**) classification by components of POE resilience; and (**c**) classification by negative impact. Experts mentioned 63 challenges (**a**,**b**) and 35 impacts (**c**) during discussion.

In the context of green transitions in POEs, the primary challenge is associated with the decision-making processes and management practices. Experts suggest that neglecting these challenges could lead to significant economic losses (Figure 2c) and decreased competitiveness, which many view as a moderate risk. In conclusion, the effective management of technological innovation within green transitions presents considerable challenges related to the management skills of the POE.

The analysis of challenges affecting the resilience of POEs highlights several key aspects illustrated in Figure 2a. Politically, ports confront issues related to technological standardization and cybersecurity threats (Figure 2a) that can disrupt operations (Figure 2c).

Technologically, outdated infrastructure poses significant barriers to technological advancement, innovations, and green transitions (Figure 3a), as it was mentioned by experts representing primary port services providers. However, it can also be seen that it is not only technological challenges that dominate; a large part of the challenges mentioned by experts from the primary port service group are also related to a lack of knowledge and management competences (Figure 3a). Experts representing logistic companies and primary service providers identified the need for planned dynamic infrastructural development, and experts from fields related to port management identified modernization needs aligned with green technologies driven by innovations in automation (Figure 3b). Notably, these challenges may also act as catalysts for accelerating green transitions in ports (expert S1EI4).

To improve the resilience of POEs (Figure 3b) and promote green transitions, experts recommend several effective managerial interventions. Key areas include sustainable development planning (S2EL4, S3EI9), investment in green technologies (S2EI1, S3EI8), stakeholder engagement (S1EL3, S1EL4, S1EI1, S1EI3, S1EI5, S2EL2, S3EI9, S4EL10, S5EL11, S5EI11), compliance and assessment (S2EL1, S3EL1, S3EI8, S4EI10, S4EL9), training and capacity building (S2EI1, S2EL1, S5EL11, S5EI11), and the adoption of green tools and strategies (S1EL1, S1EI1, S1EI3, S2EL1, S2EL2, S4EL10) for the integration of environmen-

tally friendly practices into strategic planning, which is essential for ensuring long-term coastal sustainability.

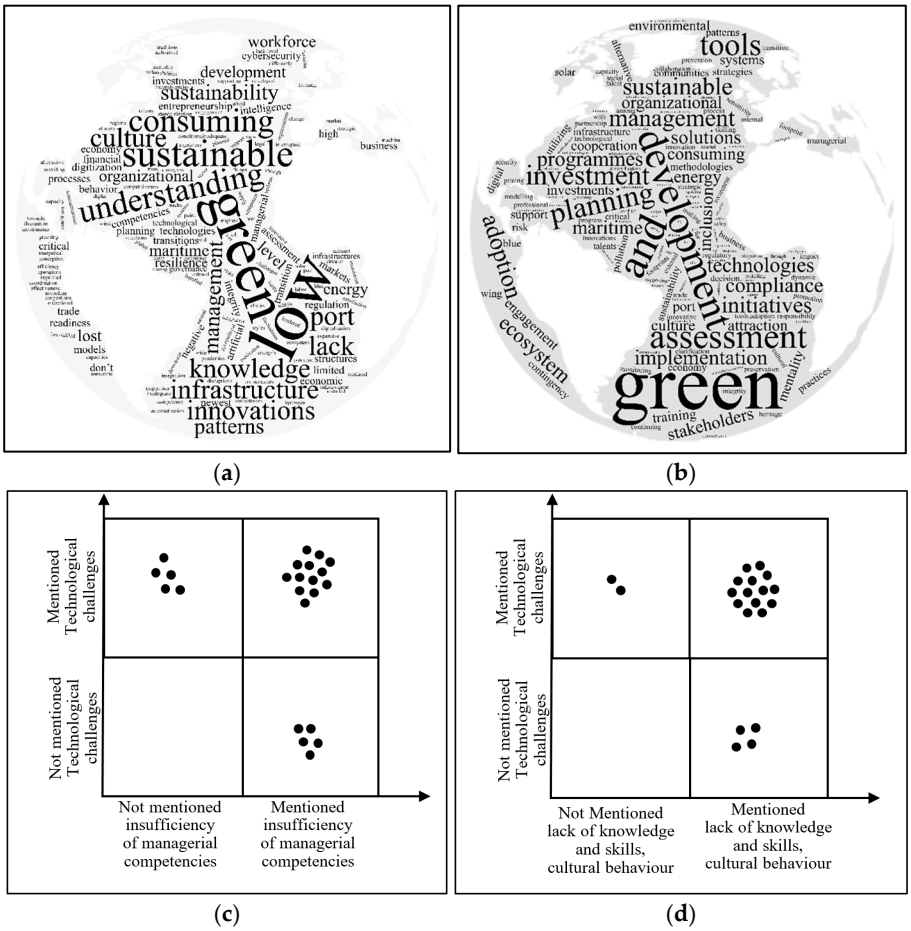


Figure 3. Visualization diagrams representing focus group interview results: (**a**) word cloud drawing presenting the dominant challenges for POEs; (**b**) word cloud drawing presenting effective managerial interventions for resisting challenges; (**c**) results of cross-content analysis for estimating the relationship between technological and managerial challenges; and (**d**) results of cross-content analysis for estimating the relationship between technological and soft organizational challenges such as knowledge, skills, and culture. In pictures (**c**,**d**) the frequency of of experts' asnswers on specific object from specific category are presented by black points.

Additionally, technological challenges are closely linked to a lack of managerial competencies (Figure 3c), affecting both green transitions and the overall resilience of coastal ecosystems. Expert analyses indicate that modern technologies require complex integration into existing systems, and without adequate managerial understanding, inefficiencies are likely to arise: Modern technology integration's relationship with the needs for adequate managerial understanding was mostly identified in the opinions of primary service providers.

Experts note that the rapid pace of technological advancement demands continuous adaptation, particularly in implementing green technologies like renewable energy systems (S1EL4, S1EI2, S1EI5, S2EL1, S3EL8, S3EI8), crucial for sustainability (S2EL2, S3EI9), but more crucial for the management of these technologies during adaptation and integration into the processes (S1EI4, S1EI5, S3ES5EL11, S41EL2, S5EI11) and sharing the responsibilities of management (S1E3, S2EL3, S2EI1, S2EI3, S3EL8, S3EI9, S5EL11, S5EI11) within the POE. During participatory observation at scientific conferences, it was identified that if a port were to begin generating energy from renewable sources, the existing energy infrastructure may not always be equipped to accommodate the generated energy volumes.

This would necessitate the expansion of the port's infrastructure, including the implementation of energy storage systems, thereby increasing costs and requiring specific external regulatory interventions. Even after addressing the infrastructure integration challenges, issues related to alternative energy management would persist, as there is a general lack of expertise in this field—not only at the seaport or national level, but also within the global maritime industry.

The cross-content analysis revealed that expert opinions highlight the critical relationship between technological challenges and the lack of knowledge, skills, and cultures of sustainability (Figure 3d) within POEs.

According to the analysis of opinions in the different stakeholders' categories, it was discovered that there are some tendencies in the distribution of opinions (Table 1). The analysis of expert opinions, as presented in Table 1, identifies 24 instances of challenges related to technological factors and managerial competencies. Of these, 13 cases (54%) demonstrate a linkage between technological challenges and a lack of managerial competencies. Additionally, 14 cases (70%) suggest an association between technological and cultural–behavioral challenges, indicating that these challenges are frequently interconnected in expert assessments. The analysis further disaggregates expert responses by stakeholder group. Among international experts, 80% of primary port service providers and 50% of governmental and non-governmental organizations identified a connection between technological challenges and managerial competencies.

Table 1. Distribution of experts' opinions among different groups of stakeholders.

Criteria	Technological and managerial challenges; frequency (percentage)		Technological and cultural/behavioral challenges; frequency (percentage)	
	Total frequency of mentions: 24 appearances Linked technological and managerial challenges in 13 cases (54%) r = 0.5; p = 0.196 > 0.05		Total frequency of mentions: 20 appearances Linked technological and cultural and behavioral challenges in 14 cases (70%) r = −0.5; p = 0.196 > 0.05	
	Lithuanian experts	International experts	Lithuanian experts	International experts
	In frequency of mentions (percentage in group)			
Primary port service providers	2 (0.4)	4 (0.8)	2 (0.4)	1 (0.2)
Management companies	2 (1)	1 (0.5)	1(0.5)	2 (1)
Governmental and non-governmental organizations	0 (0)	1 (0.5)	1(0.5)	0 (0)
Hinterland logistics service providers	1 (1)	0 (0)	0 (0)	1 (1)
Researchers	1 (1)	1 (1)	1 (1)	1(1)

By contrast, Lithuanian experts highlighted this link more frequently within port management organizations and logistics sector representatives. With regard to the relationship between technological challenges and cultural/behavioral factors, Lithuanian experts most often noted this relationship among primary port service providers and governmental/non-governmental organizations. International experts, however, emphasized this connection within port management and logistics service providers.

While the data reveal differences between expert groups and stakeholder categories, these differences do not provide strong empirical evidence of a meaningful relationship in opinion differences between different group of stakeholders. While there is a moderate correlation in both categories the p-value of 0.196 (greater than 0.05) indicates that these both correlations are not statistically significant, suggesting that the opinion differences may not be robust enough to draw generalizable conclusions.

The research results and discussions found out that advanced technologies, crucial for sustainability, require sophisticated integration. However, without a skilled workforce, this

integration can be inefficient and error-prone. Experts emphasized that the rapid pace of technological evolution demands continuous learning and adaptation, yet gaps in knowledge prevent timely adoption, leaving ports lagging. Additionally, implementing green technologies like renewable energies necessitates specific expertise, which is often lacking, making sustainable practices difficult to adopt effectively so declared green transitions move slowly or stop for some time because these reasons. By resuming research results and content analysis it could be mentioned that green transition of POE also can accelerate green transitions because enhancement of POE resilience for the resisting technological challenges influence more clear and fast implementations of engineering innovations and supports the green transitions. But for the effective green transitions' acceleration it is very important to ensure high managerial competencies for the implementation managerial interventions at the time the uncertainties negatively influence POE functioning, and upskilled and reskilled workforce with the strongly developer sustainable consuming and sustainable organizational culture.

4. Discussion

This research highlights the crucial link between POE resilience and the successful implementation of green transitions. A key barrier identified is the lack of a comprehensive 'green rates' evaluation methodology. Without such a framework, it is challenging to benchmark progress and develop consistent policies across the port sector. While acknowledging the importance of technological advancements, the study emphasizes that managerial competencies are critical for accelerating green transitions, especially in the conditions where the methodology of green transitions' assessment is not elaborated yet [20,25]. The study identifies several critical challenges within POEs, including outdated infrastructure, cybersecurity vulnerabilities, and insufficient managerial skills, all of which impede the integration and management of green technologies, as outlined in previous research [19,21,23]. These findings align with prior studies that emphasize the pivotal roles of leadership, human resource management, and stakeholder engagement in advancing green transitions [7–9,14,15].

The research identifies several key implications for policymakers, port managers, and stakeholders. POE companies and organizations must invest in training and development programs to equip managers with the skills and knowledge necessary to effectively lead the transition process [10,14,30]. Cultivating a workplace environment that encourages innovation, embraces change, and promotes continuous learning is crucial for overcoming resistance to change and promoting the adoption of green practices and transitions [9]. POEs must actively address the technological challenges associated with green transitions, including outdated infrastructure, cybersecurity threats, and the need for ongoing investment in new technologies [11,16]. Building strong partnerships with stakeholders, including government agencies, industry associations, and environmental organizations, is critical for creating a supportive environment for green transitions. These findings directly confirm the hypothesis that not only technological innovations force green port development, but the newest technological innovations and dynamic management skills can accelerate green transitions in the POE through the implementation of effective managerial interventions detailed previously.

This research identifies several avenues for future research. A deeper investigation of the specific challenges and how they impact managerial decision-making could involve examining the specific managerial skills and competencies needed to overcome each technological challenge, as well as the factors that hinder the development of these skills. Further exploration of the specific roles and contributions of stakeholder partnerships could involve identifying the key stakeholders involved in green transitions, their respective roles and responsibilities, and the challenges they face in working together. The study identifies several potential managerial interventions for accelerating green transitions. Future research could focus on evaluating the effectiveness of these interventions in practice. This could involve

conducting case studies of ports that have implemented different managerial interventions and comparing their outcomes.

This study acknowledges the limitations of qualitative research methods and limitations arising from its focus on a specific context. Contextual limitations are related to the selection of regions. The Klaipeda port, a mid-sized port in Lithuania, as a national state-owned seaport located in a non-capital city, influenced the structure of the focus group interview participants according to the strategies of the sampling methodology, ensuring the validity and reliability of research. This choice, while providing valuable insights, restricts the generalizability of findings, potentially omitting arguments and facts relevant to larger ports. Methodological enhancements, incorporating a wider range of ports and stakeholders and employing multicriteria decision methodologies, would be beneficial for identifying more generalized managerial intervention frameworks to accelerate green transitions and enhance the resilience of POEs, and could be implemented in the continuity of this research.

This discussion should acknowledge the limitations inherent in qualitative research, including researcher bias and confirmation bias, despite employing purposeful and stratified sampling. While these sampling methods enhance validity and reliability, they do not fully eliminate the risk of overlooking contradictory evidence. To mitigate this risk, the study incorporated participative observation and iterative feedback discussions of the results with the researchers and experts, thereby strengthening the trustworthiness of the findings. Future research, as it is planned in methodology of the project, will quantitatively assess the relative importance of managerial interventions on resilience enhancement and the acceleration of green transitions.

5. Conclusions

In conclusion, the research findings underscore the pivotal role of managerial skills and organizational cultural shifts in enabling the successful implementation of green transitions within ports. Moreover, the study identifies a critical relationship between technological advancements and managerial challenges, highlighting that technological progress demands improved competences in technological systems management at all levels of POEs. By prioritizing investment in these areas, ports can effectively overcome obstacles and accelerate their journey towards sustainability.

The findings also emphasize the absence of a standardized methodology for assessing 'green rates,' which presents a significant barrier to tracking and measuring progress in environmental transitions. This gap in evaluation frameworks limits the ability of port authorities to establish clear benchmarks and systematically manage green innovations.

To address these challenges, a comprehensive and collaborative approach involving stakeholders from government, industry, and environmental organizations is essential. Only through such coordinated efforts can ports play a leading role in shaping a greener, more resilient maritime sector. Developing a robust methodology to measure and track green transitions, alongside enhancing managerial capabilities, is key to driving sustained progress towards environmental goals.

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