FRAMEWORK OF MANAGERIAL INTERVENTIONS FOR THE ENHANCEMENT OF PORT ORGANIZATIONAL ECOSYSTEM'S RESILIENCE

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Abstract. The purpose of this research is to present a conceptual model of Port Organizational Ecosystem (POE) resilience and to develop a framework of managerial interventions to enhance POE resilience in the conditions of high uncertainties. Utilizing a mixed-methods approach, data were collected through focus group interviews and analysed using thematic and statistical methods. The analysis identified key challenges, including global supply chain disruptions, technological advancements, and governance-related issues, emphasizing the critical role of adaptable governance frameworks in mitigating these challenges. Findings reveal that while technological innovations pose challenges, they also offer tools to enhance operational sustainability and resilience. The research highlights managerial weaknesses that complicate these challenges, underscoring the need for managerial interventions focusing on engagement, diversification, and compliance. Research implications suggest the necessity for adaptive leadership and governance structures that promote inclusivity and strategic foresight. Practically, this paper outlines a framework of managerial interventions for improving POE resilience, offering valuable insights for port authorities to integrate worldwide best practices into their operations. This study contributes original insights by linking governance patterns with resilience enhancement, providing a structured approach to understanding and improving POE resilience in the global maritime landscape.

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1. Introduction

In the contemporary landscape of global supply chains and logistics, maritime businesses operate not in isolation but within complex organizational ecosystems. Traditional strategies and theories are increasingly inadequate for addressing the dynamic demands of sustainable port development and maritime business resilience. Competition among port enterprises now extends beyond traditional supply chains to include collaborative competition within the port organizational ecosystem (POE). Modern seaports are evolving beyond their historical roles as purely infrastructural entities; they now serve as profit centres for diverse stakeholders, including shippers, energy companies, importers, exporters, and port authorities. Consequently, the stakeholders of the port logistics chain encompass a comprehensive array of entities involved in international trade, such as terminal operators, customs, and transport companies.

Seaports can be described as multifaceted port organizational ecosystems characterized by intricate operational

and maintenance processes integrating activities to ensure the efficient flow of materials and information. These processes also consider the diverse institutional and cross-functional dimensions within the ecosystem, emphasizing business excellence and efficient support infrastructure (Asadabadi & Miller-Hooks, 2018; Golzarjannat et al., 2021).

In the global supply chain (GSC) network, the resilience of the POE is a critical factor influencing the smooth operation of global trade networks and the stability of the global economy. The resilience of the POE extends beyond operational efficiency and plays a crucial role in enhancing connectivity, mitigating disruptions, fostering adaptability, and supporting coastal sustainability, all vital to global trade dynamics. So, the acknowledging the critical importance of POE resilience, this research investigates managerial mechanisms which are the necessary to enhance and sustain the resilience of POE. Achieving optimal resilience in the POE requires more than the establishment of effective governance according to known port governance patterns (Brooks & Pallis, 2012). It involves developing and

implementing a comprehensive portfolio of managerial interventions to strengthen the POE against external shocks and enable swift recovery from unpredicted negative influence.

This study pursues two primary objectives: first, to construct a robust conceptual model identifying the key dimensions and determinants of POE resilience; second, to elaborate framework of strategic managerial interventions designed to enhance POE resilience. The research methodology integrates theoretical insights with empirical analysis, utilizing a semi-structured focus-group interview approach. By combining theoretical approach and empirical analysis, this study provides a robust analytical framework for examining the proposed managerial interventions. Through this approach, the research aims to contribute valuable insights into the interplay between managerial interventions and the resilience of POE, thereby enhancing the broader discourse on port management and global supply chain resilience.

2. Theoretical framework of managerial interventions for the enhancement resilience of port organizational ecosystem

The concept of the POE integrates frameworks from organizational, business, port, and entrepreneurial ecosystems. Verhoeven (2010) introduced the idea to describe the evolving role of port authorities in regulation and value creation. Van Leeuwen (2015) later highlighted governance through ecosystem-based management, while Ibrahimi (2017) emphasized ports' interactions with maritime business units in shared environmental conditions. Through the lens of adaptive complex systems theory, ports reveal a structure characterized by non-linearity, interconnection, and a constant interplay of influences (Li et al., 2020). Recent research aligns the POE with organizational ecosystems, fostering interactions among internal and external entities that affect an organization's functionality and sustainability. In turn, ports operate as networks of interconnected entities with common goals, forming clusters of seaports characterized by sustainable development objectives. This model divides the ecosystem into three layers: the port authority as the central figure, the operational system of services as the seaport, and business companies from hinterland and foreland sectors, collectively representing the POE (Haezendonck & Langenus, 2019).

Within this framework, actors of the POE, as illustrated in Figure 1a, are categorized within the OST and organizational ecosystem (OE), forming various chains and networks with diverse relationships and interests. Positioned at the ecosystem's centre, the port authority (PA) is the primary actor concerned with the seaport cluster's strategic success, whether in sea or land regions or competitive markets, especially in the context of global supply chain resilience (Merk, 2020; Merk et al., 2022). At the OST level, represented in Figure 1a by six smaller circles, are actors such as private firms (PP), concurrent (CO) or partner (PP) ports, labour organizations (LO), non-profit organizations (NPO), including chambers of commerce and industry, universities, and research institutes. Various government agencies (GA) are also included. These actors facilitate port operations, land and sea transport, and shipping agency activities, creating value-added services (VAS) and value-added logistics (VAL). These services and logistics connect to the foreland and hinterland sectors through multimodal transport operators (MTO) and freight forwarders (FF) (Ibrahimi, 2017).

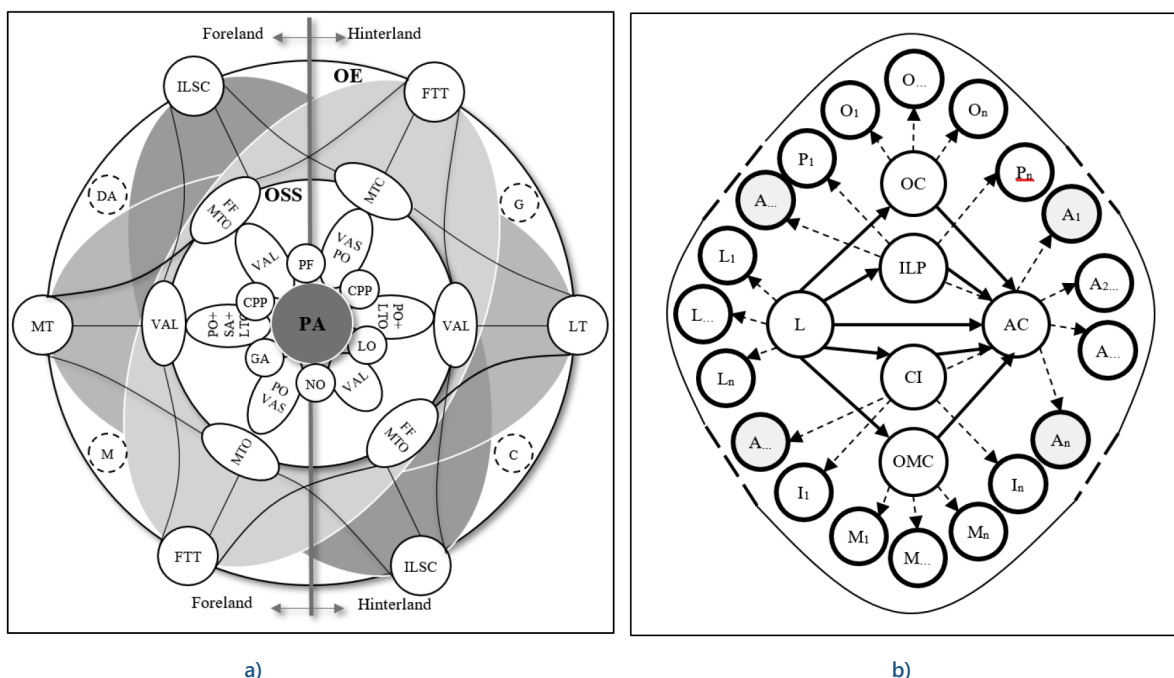a)   b)

Figure 1. Conceptual and theoretical models of port ecosystem coordination and organizational resilience: a) – conceptual model of POE (Ibrahimi, 2017); b) – theoretical model of organizational resilience (Moser et al., 2019)

The complexity of the POE within the global supply chain and its high level of internationalization reflects the external environment's multifaceted nature. Previous research, such as Valionienė and Kalvaitienė (2023), has shown that this multilayered complex system of external factors can exert both positive and negative impacts on each organization individually and the organizational ecosystem collectively. Transformations in governance, management methods, and business model patterns can result from these influences. The complexity further amplifies when the ecosystem encounters a double effect of externalities, impacting the external and internal environments with both positive and negative factors for organizations. Such high external environmental complexity, combined with strong uncertainties, can destabilize organizational ecosystem operations, leading to disruptions and negatively affecting national economies and the functioning of the global supply chain (Bode & Wagner, 2015; Coşkun & Erturgut, 2023).

A detailed analysis of potential POE disruptions indicates that various uncertainties can impact business processes, exploiting vulnerabilities across critical infrastructure, managerial practices, human resources, and organizational culture (Nguyen et al., 2021; Haezendonck & Langenus, 2019). Traditional risk management approaches may fall short due to the complexity of economic, regulatory, and environmental shocks in the maritime industry (Purwitasari et al., 2025).

According to the theoretical model of organizational resilience (Figure 1b), certain managerial interventions, such as managerial practices, can serve as effective short-term solutions in response to unforeseen external or internal environmental changes. These interventions aim to maintain resilience, facilitate rapid recovery, and enable adaptation to altered conditions, while also describing organizational managerial capacities (Figure 1b). Consequently, the resilience of the Port Organizational Ecosystem (POE) emerges as a crucial aspect of port governance.

As illustrated in Figure 1b, organizational resilience is a complex structure consisting of six key interrelated components. The two primary components are leadership (L) and adaptive capacity (AC), which function through the supporting elements of organizational culture (OC), individual resilience (ILP), critical infrastructure (CI), and organizational managerial capacities (OMC). By developing and strengthening these components, organizations and organizational ecosystems can enhance specific resilience factors. In the context of organizational ecosystems, there is a high probability that different organizations can compensate for each other's weaknesses through their well-developed strengths. Therefore, based on the structure of the POE (Figure 1a) and the conceptual model of organizational resilience (Figure 1b), it can be concluded that the developed POE resilience model builds upon previous findings. Specifically, it reinforces the idea that strong leadership enhances an organization's adaptability to external factors by developing managerial interventions in the areas of organizational culture, individual resilience support,

critical infrastructure development, and the strengthening of organizational managerial capacities.

Organizational resilience models emphasize that managerial interventions can offer effective short-term solutions for adapting to external and internal changes, underscoring the importance of resilience in port governance (Morales et al., 2019). Effective leadership fosters an organizational culture that prioritizes learning and innovation, which is essential for navigating uncertainty (Becker & Kretsch, 2019; Brooks & Pallis, 2012). In the chaotic contexts of the maritime industry, the importance of leadership and intuition is underscored by Valionienė and Kalvaitienė (2023), who describe leadership as the primary functional driver for enhancing maritime business excellence and resilience to external unpredictability.

Moreover, integrating digital technologies into port operations enhances resilience by improving data analytics and decision-making, enabling ports to respond more adaptively to disruptions (Almeida, 2023; He et al., 2023; Ferreira, 2024). In summary, managing uncertainties requires implementing practices informed by the POE resilience model, addressing key components like infrastructure, human resources, and culture. A comprehensive framework involving strong leadership, continuous learning, and innovation adoption is crucial for ports aiming to thrive amidst global supply chain uncertainties (Burnard & Bhamra, 2011; Valionienė & Plačienė, 2022). Further analysis and classification of these factors are necessary for effective management.

A deeper analysis of external negative uncertainties reveals that these factors can be classified into at least a three-dimensional system due to their inherent complexity (Figure 2a). Global supply chain connections mean that disruptions – like ship rerouting or inefficient resource use – can significantly affect business (Valionienė & Plačienė, 2022; Rose & Wei, 2013). These uncertainties stem from operational, security, technical, organizational, and natural factors (John et al., 2016; Berle et al., 2011):

- operational: equipment failures, vessel accidents, cargo spills, and human errors;
- security and safety: sabotage, terrorism attacks, failures in surveillance systems, and arson;
- technical: inadequate maintenance of equipment, navigational systems, IT infrastructure, and dredging;
- organizational: labour unrest, disputes with regulatory bodies, interorganizational conflicts, and congestion;
- natural: hydrological, atmospheric, geological, and seismic uncertainties (Hossain et al., 2019). This broad category highlights that ports frequently face disruptions arising from both natural disasters and cyber-attacks, significantly compounded by the increasing reliance on technology and interconnected systems (Ferreira, 2024).

Ports face a complex, multi-dimensional system of external uncertainties that significantly impact their operations. Global supply chain dependencies mean disruptions, such as ship rerouting, can profoundly affect port business

(Valionienė & Plačienė, 2022; Rose & Wei, 2013). These disruptions encompass operational, security, technical, organizational, and natural challenges (John et al., 2016; Berle et al., 2011), with threats ranging from equipment failures and sabotage to maintenance issues and environmental risks (Hossain et al., 2019; Ferreira, 2024).

To effectively manage these vulnerabilities, which span economic levels from micro to giga, ports require comprehensive strategies (Valionienė, 2020; Rose, 2004). Specifically, climate change, technological failures, and cybersecurity risks necessitate enhanced crisis management and strategic integration (Asariotis et al., 2024; Chen et al., 2019; Huang et al., 2023). Developing a robust resilience framework is crucial. This framework should focus on strengthening infrastructure, leadership, human resources, and organizational culture. By fostering continuous learning and encouraging innovation, ports can enhance their adaptability and maintain connectivity within the global supply chain (Burnard & Bhamra, 2011; Phan et al., 2019). Collaborative learning and multi-level stakeholder engagement are crucial for port sustainability and adaptive coastal development (Valionienė & Zuperkienė, 2024). Such an integrated approach ensures that port ecosystems are better equipped to withstand and recover from diverse uncertainties, supporting long-term sustainability and competitiveness.

These findings suggest that uncertainties can be conceptualized in a two-dimensional model, categorized into functional groups of managerial interventions (Figure 2b). This complexity evolves into a three-dimensional model, enhancing the POE's ability to manage situations through strategic interventions:

- political uncertainties: managerial strategies can enhance resilience against political challenges by enhancing governance structures and enabling rapid regulatory responses (Burnard & Bhamra, 2011);

- economic uncertainties: targeted interventions, like financial risk management, can fortify resilience against economic fluctuations, ensuring competitiveness and sustainability (Asariotis et al., 2024);
- social uncertainties: interventions can address socio-economic and cultural issues, promote sustainable development, and build trust with local communities through engagement initiatives (Gallo et al., 2021);
- technological uncertainties: investing in digital infrastructure and cybersecurity helps ports remain competitive and agile, mitigating technology-related vulnerabilities (Ćelić et al., 2025; Valioniene et al., 2024);
- environmental uncertainties: managerial actions can navigate ecological challenges by adopting green technologies and optimizing practices to meet sustainability goals (Valionienė & Plačienė, 2022; Liu et al., 2025).

By implementing these targeted managerial interventions, POE can enhance their resilience and adaptability across various dimensions of uncertainty. And the implementation of managerial interventions in key organizational fields – managerial capacities, critical infrastructure, organizational culture, and human resource management (MICH) – is essential for enhancing resilience in the POE amidst various uncertainties.

- strengthening managerial capacities equips leaders with skills to make informed decisions during uncertainty, with training programs focusing on adaptive leadership and strategic foresight (Burnard & Bhamra, 2011) and developing robust risk assessment frameworks ensures sustained operations (Akpinar & Ozer Caylan, 2023);
- human resource management fosters a skilled, adaptable workforce through continuous professional development, diversity initiatives, and employee well-being programs and a culture of empower-

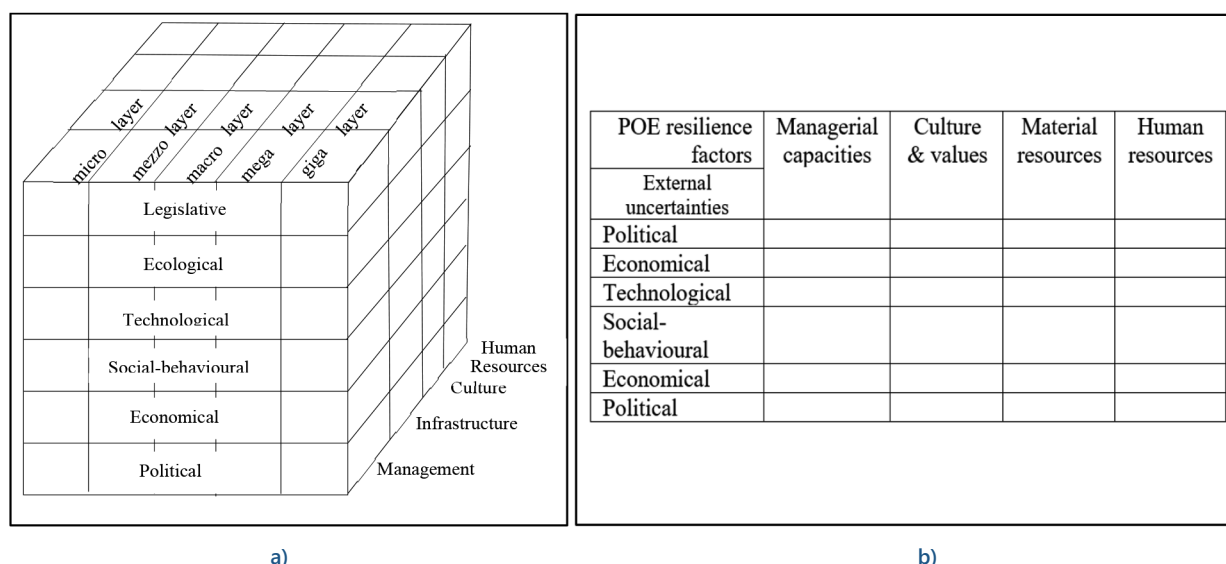| POE resilience factors	Managerial capacities	Culture & values	Material resources	Human resources
External uncertainties				
Political				
Economical				
Technological				
Social-behavioural				
Economical				
Political				

a)   b)

Figure 2. Theoretical: a) three-dimensional model for the classification POE uncertainties (Valionienė & Župerkienė, 2024); b) – framework of managerial interventions for enhancement of POE resilience

ment promotes proactive problem-solving, helping the POE navigate socio-economic and technological challenges (Becker & Kretsch, 2019);

■ investing in critical infrastructure is vital for operational resilience and priority should be given to modernizing facilities and integrating advanced data analytics (Huang et al., 2023), at the same time the effective maintenance and contingency plans will mitigate risks associated with technical disruptions (Asariotis et al., 2024);

■ a strong organizational culture fosters resilience through collaboration, continuous improvement, and sustainability principles, preparing ports to handle socio-economic and environmental uncertainties (Gallo et al., 2021; Valionienė & Plačienė, 2022).

In summary, targeted managerial interventions across these domains are crucial for operational continuity and sustainable growth in the face of political, economic, social, technological, environmental, and legal challenges. Unmanaged uncertainties can lead to significant disruptions, exemplified by the 2021 Suez Canal blockage (Haezendonck & Langenus, 2019), underscoring the need for adaptive resilience strategies that ensure ongoing effectiveness in a fluctuating environment. Analyzing uncertainties within this structured framework enhances the understanding of port sector challenges and guides the development of effective interventions to maintain competitive advantage in an increasingly complex global landscape.

3. Research methodology

This research utilized a focus group interview methodology (Kairuz et al., 2007), bringing together small groups to delve deeply into perceptions related to resilience in the maritime industry. It is important to mention that during the pre-research stage, participatory observation was conducted during various conferences and professional scientific discussions, revealing that POE resilience concept remains largely theoretical and is not yet widely recognized or understood among practitioners as the topic of POE risk management. Through participatory observation, it was possible to assess practitioners' levels of awareness and engagement with the topic, revealing that POE resilience is predominantly an academic construct with limited managerial integration at the moment of research implementation. Given this gap in practical knowledge, traditional qualitative research methods such as in-depth individual interviews or case studies were deemed less suitable, as they typically require participants to have a pre-existing familiarity with the problem research field. Additionally, it should be mentioned that based on the theoretical analysis no well-established system of factors for assessing POE resilience were found, making it challenging to apply predefined qualitative or mixed-method approaches. So, methodology of focus-group based on the pre-research stage investigation was choose by reasoning for the following argues:

■ exploratory nature of the topic: since POE resilience is an emerging and largely theoretical concept (Valionienė & Kalvaitienė, 2023), engaging professionals in structured discussions allowed for a more dynamic exploration of their perspectives, experiences, and managerial insights. The interactive nature of focus groups enabled participants to collectively construct knowledge and identify relevant resilience factors and managerial interventions, which would have been more difficult to achieve through isolated individual interviews. According to the methodology of focus group interviews, all participants perceive these discussions as non-threatening, encouraging them to express any opinion freely, whether it is shared by other participants (Krueger, 2009).

■ context-specific managerial insights: given that the research primarily focuses on managerial aspects of POE resilience, a collaborative discussion format facilitated a richer exchange of ideas. This was particularly valuable since resilience is not a universally defined metric but rather a context-dependent construct influenced by specific organizational and environmental factors. Focus groups provide valuable insights, particularly when participants represent thematically related interest groups often overlooked by quantitative research (Morgan, 1997). These are main reasons influenced the research methodology construction.

■ integration of participatory observation findings: the participatory observation method, employed during academic and industry events, provided preliminary insights into knowledge gaps and managerial concerns regarding POE resilience. These observations informed the structure and content of the focus groups, ensuring that discussions were centered on the most critical and relevant aspects for practitioners including more moderation flexibility based on the results of participative observation;

■ identification of key factors: since no predefined system for assessing POE resilience was available at the study's outset, an inductive approach was required. Focus groups enabled the identification and validation of essential resilience components through real-time dialogue, helping to establish a managerial intervention framework grounded in empirical insights.

Enhancing Practical Applicability: Given that POE resilience is a novel concept for many practitioners, focus groups provided a structured yet flexible format for engaging industry experts in meaningful discussions. The method allowed participants to critically examine and refine the conceptual model, ensuring its alignment with real-world managerial challenges and decision-making processes.

In this research two focus groups were established: one consisting of experts from Lithuania's maritime sector and another comprising participants from France, Slovenia, Germany, Latvia, Estonia, and Poland. This selection captures diverse perspectives across various geographical

contexts vital to resilience studies. A combination of purposeful and stratified sampling guided participant selection. Purposeful sampling targeted individuals based on their expertise and relevance to the research objectives, ensuring insights from stakeholders within the maritime industry and related scientific fields (Patton, 2015). Stratified sampling was employed to ensure representation across key subgroups (Barbour, 2007) within the POE, such as primary port service providers, management companies, governmental and non-governmental organizations, and logistics service providers. The distribution of stakeholders was informed by previous research (Grainger & Achuthan, 2014; Ibrahimi, 2017; Shaw et al., 2017; Valionienė, 2020) with primary port service providers comprising 44% of participants, management organizations 15%, government and NGOs 15%, logistics providers 15%, and scientists 1%. This meticulous sampling approach provided a balanced and comprehensive dataset, reflecting a wide array of functional roles and ensuring a thorough exploration of the subject matter and distribution of experts according to this stakeholders' distribution scheme is presented in Table 1.

The structured agenda addresses the challenges of enhancing resilience within the POE and their impacts on co-evolution and competitiveness in the global supply chain. Key aspects of the agenda include the port authority's role in managing POE resilience, its potential entrepreneurial role within the ecosystem, and the discussion of possible managerial interventions for handling external emergencies and externalities. 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. Are these challenges dependent on the governance pattern of the POE? If so, how can this dependence be explained?
3. What managerial interventions can be utilized to withstand external uncertainties affecting the POE, and how can these interventions be managed?

These questions are formulated based on a theoretical model of organizational resilience that establishes connections between ecosystem governance patterns and their influence on key resilience components. The management of these components through leadership aims to increase adaptive capacity, predicting a logical structure of analysis methodology presented in the following figure.

Data collection was started after the IRB improvement for this research and was conducted through remote meetings using Zoom, facilitated by an international group using NVivo software, with a semi-structured discussion guide. All participants express their free and not forced participatory agreement and they consented voice recording. A moderator facilitated the discussions, encouraged participation, and ensured that all relevant topics from the structured agenda were covered. The conversations were audio-recorded to capture participant responses verbatim. Audio recordings were transcribed, and field notes were taken to document differing opinions or other important remarks. However, participant reactions and non-verbal cues were not considered in the analysis. The data collected provided rich qualitative information for subsequent analysis.

Thematic analysis was used to analyse focus group data, with transcripts coded by stakeholders' functional and international types. The analysis included three main stages aligned with the agenda questions: classification and impact assessment, identification of governance

Table 1. Structure of POE's stakeholders invited in focus group interview

Type of stakeholders	Lithuanian group	International group
Representatives of general cargo operations and services providers in ports (5 experts in each group, 46%)	Representatives from Lithuanian stevedoring companies' association, shipowners' association, agents and forwarders association, also representatives of the biggest port warehouse's services providers, and container terminal (transcription codes S1EL1, …, S1EL5)	Representatives of the central association of Germany port operators, of Gdansk port container terminal, the association of Polish maritime industries, Estonian logistics & freight forwarding association, Latvian ship suppliers association (transcription codes S1EI1, …, S1EI5)
Port governance's representatives (2 experts in each group, 18%)	Representatives of Klaipeda seaport authority and Klaipeda city municipality (transcription codes S2EL6, S2EL7)	Representatives of HAROPA port authority and port authority of Koper port (transcription codes S2EI6, S2EI7)
Representatives of other port private and public organizations (2 experts in each group, 18%)	Representatives of Lithuanian transport safety administration, towage services' providing company (transcription codes S3EL8, S3EL9)	Representatives of Slovenian maritime administration, Germany federal maritime and hydrographic agency (transcription codes S3EI8, S3EI9)
Representatives of hinterland companies and other maritime related services providers (1 representative in each group, 9%)	Representatives of Lithuanian national road carriers' association "LINAVA" (transcription code S4EL10)	Germany port technology association (transcription code S4EI10)
Representatives of scientific research in maritime field (1 representative in each group, 9%)	Klaipeda university researcher (transcription code S5EL11)	Researcher from university of Normandy in Le Havre (transcription code S5EI11)

parameters, and development of managerial interventions for enhancing POE resilience (Figure 3).

In the first stage, challenges were initially classified using the PESTEL framework, assessing political, economic, social, technological, environmental, and legal impacts on the POE's resilience (Valionienė & Plačienė, 2022). Challenges were further categorized by four resilience components: critical infrastructure, human resources, managerial capacities, and organizational culture. These categorizations helped determine the extent of their influence, identifying challenges as strong, moderate, or generalized in their impact on the POE.

During the second stage of the research (as shown in the figure), the main functional parameters of seaport governance were identified to develop potential managerial interventions. These interventions are aimed at proactively managing uncertainties and unforeseen events in the internal and external environments of the POE. The outcome of this analysis was the identification of effective governance criteria designed to enhance POE resilience and minimize potential negative influences. The final stage involved identifying and classifying managerial interventions into a matrix. This informed the design and implementation of a comprehensive framework aimed at enhancing the resilience of the POE, ensuring it remains adaptive and sustainable.

Also, actions for the validity and reliability of research should be detailed as it is presented in the Table 2.
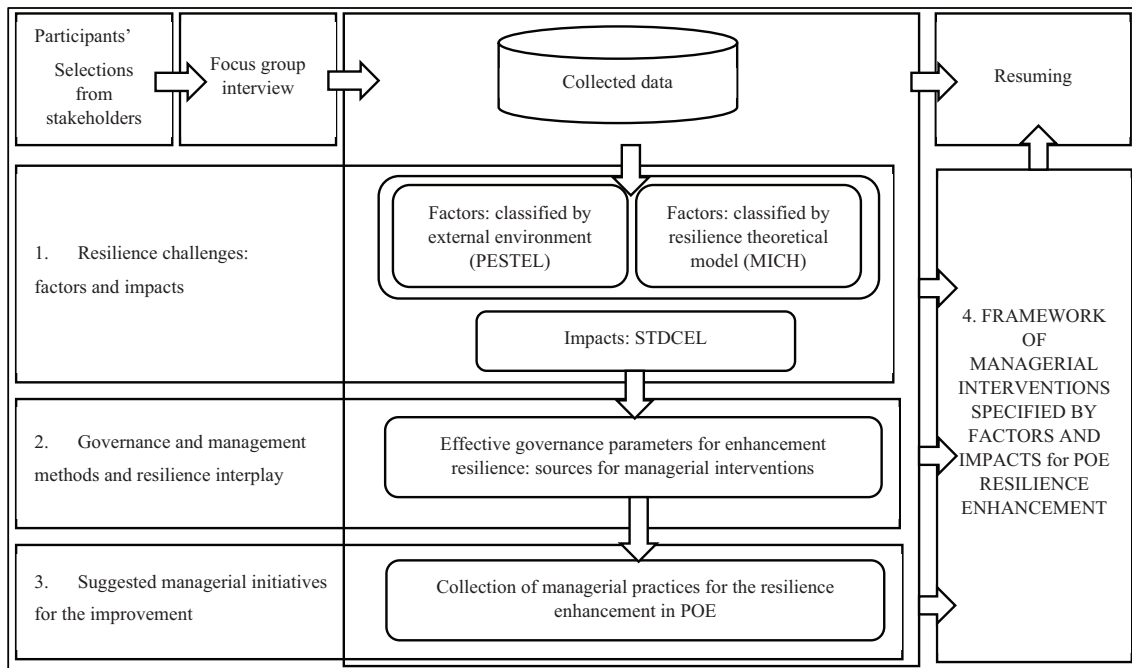

Figure 3. Data analysis algorithm of empirical research

Table 2. Research validity and reliability criteria

Validity		Reliability	
Content Validity	By employing purposeful and stratified sampling, your research ensures that all relevant stakeholder groups within the maritime industry are represented. This comprehensive inclusion enhances content validity by capturing a full spectrum of perspectives necessary to address the research questions thoroughly	Consistency	The structured approach of forming focus groups with experts from similar strata and backgrounds ensures consistency in data collection. This stratified framework allows for comparisons across similar groups, enhancing the reliability of insights drawn from the discussions.
External Validity	The study's external validity, or generalizability, is bolstered by the careful selection of experts from multiple countries and regions within the maritime industry. This geographic and functional diversity helps ensure that the findings are not limited to a single context and could potentially be applicable to similar industries globally	Repeatability	Although qualitative research is inherently less replicable than quantitative studies, the use of well-defined sampling criteria and methodology increases the repeatability of the study. If another researcher follows the same sampling methods with similar criteria, they should obtain comparable participant groups and potentially similar findings.
Construct	Construct validity is strengthened by selecting participants based on specific criteria related to the research constructs (e.g., stakeholders in port operations). Purposeful sampling ensures that participants genuinely represent the constructs being studied, allowing for meaningful exploration of research questions.	Stratification	Stratified sampling contributes to reliability by mitigating potential biases that might arise from an unbalanced representation of different stakeholder groups. Ensuring each subgroup is proportionally represented means that the data reflects the true diversity and distribution of viewpoints within the maritime sector.

Reliability was ensured by strategically selecting experts from diverse shipping regions with varying governance patterns, focusing on middle-sized and smaller ports due to their vulnerability to external uncertainties. A significant number of participants were from the Baltic Sea region, particularly Lithuania, Latvia, Estonia, and Poland, to address prevalent regional issues. Participants needed at least five years of managerial experience and relevant expertise. To ensure validity, data were cross-verified to identify inconsistencies within stakeholder groups and across different fields of interest. Remote discussions gathered expert feedback on the conclusions, which were integrated into the final analysis. These measures enhanced the study's credibility and the robustness of its findings.

By summarizing the research methodology approach, it could be said that by combining purposeful and stratified sampling, the research design effectively addresses issues of both validity and reliability. The deliberate selection of experts ensures relevant, rich, and diverse data, while stratification guarantees a systematic representation of all key groups involved in the study. This methodological rigor supports the credibility of research findings, facilitating robust and insightful conclusions about the POE's resilience dynamics and resilience enhancement possibilities by using some managerial interventions in the context of proactive management of uncertainties.

4. Discussion research results

4.1. Uncertainties of contemporary POE in the context of resilience

The analysis of the focus group interviews revealed key groups of uncertainties affecting the POE, which are categorized and presented in Table 3. These groups include global supply chain disruptions, technological disruptions, environmental sustainability issues, infrastructure constraints, collaboration among POE actors, trade volatility and economic uncertainty, POE governance, human capital and talent management, and cybersecurity risks. Notably, certain challenges were frequently mentioned during discussions, and these frequencies were considered for a deeper analysis of the interview content.

As illustrated in the Table 3, one set of disruptions is associated with global-level challenges. Issues such as geopolitical tensions in various regions, pandemics, or natural climatic disasters negatively impact not only the global supply chain but also the POE as an integral part of it. According to the experts, these unmanaged challenges could severely affect the port ecosystem, ranging from simple bottlenecks to the complete closure of ports, leading to disruptions in global supply chains and necessitating rerouting and infrastructural changes. An expert from a stevedoring company noted, "This type of challenge is the most difficult to manage" (S1EL1). Similarly, a port governance expert stated, "These challenges are usually unpredictable, and the port community must be ready to accept them flexibly" (S2E16). Furthermore, an expert

from the hinterland connections group highlighted these challenges as critical risks to the resilience framework, emphasizing the need for flexible leadership to manage political uncertainties, which poses a significant challenge to governance structures in maritime affairs (S4E10).

The second group of challenges (Table 3) relates to technological integration, automation, and digitization processes within the maritime sector. These challenges are global in nature, driven by trends set by major technological innovators. Slow technological evolution and delayed digitization can lead to not only the loss of clients and cargo but also closures and disruptions if technological advancement does not meet the general digitization standards of the supply chain. Experts indicated that these developments necessitate significant investment. Experts (S1EL1, S1EL4, S1EL5, S2E16, S1EI2, S1EI3, S5EL11, S5EI11) also pointed out the need for increased investment in infrastructural development and workforce reskilling to prepare for new working conditions.

Closely related to these technological challenges is the group concerned with infrastructure development (Table 3). In the context of digitization and accelerating automation of port operations, infrastructure development requires not only financial resources and human capital development but also new strategies and management practices to maintain connectivity and competitiveness within the POE. It is particularly crucial in tackling environmental challenges, which necessitate the development of new methodologies and strategies for progress assessment and alignment with digitization and infrastructural development goals. All experts emphasized the importance of these factors, with private sector experts involved in port operations noting the critical nature of cybersecurity challenges, driven by increased automation and digitization in ports. As one expert mentioned, "In the context of rapid digitization and automation at terminals, it is vital to develop best practices not only for general port resilience and management practices but also for resilience against cyberattacks and other digital disruptions due to a lack of regulation, self-assessment, and methodological preparedness worldwide" (S3E19).

Additionally, the experts stressed the importance of enhancing managerial practices to bolster collaboration within the POE for more "effective resilience development throughout the ecosystem, including community involvement" (S1EI3). "A lack of collaboration within the POE can lead to diminished operational effectiveness" (S1EI3). These challenges are also linked with inconsistencies in governance, with experts noting variations in port governance implementation across different regions, potentially related to fluctuations in global trade patterns. Challenges in talent management emerged as another critical area, influenced by the demands of updated infrastructure, technologies, and concepts (S2EI7, S5EI11). "A low-skilled workforce can hinder innovation" (S2EI7), while "an outdated organizational culture can impede transitions within the POE" (S5EI11). Conversely, "a culture fostering innovation can set new priorities and drive the development of a

Table 3. Challenges of POE resilience framework in contemporary environment and their possible result on POE resilience

Group of uncertainties	Challenging factor for POE resilience	Possible result of negative impact
1. Global supply chain disruptions	Increasing the frequency of unpredicted events in the global supply chain, natural disasters influenced by the factor of climate changes, pandemics, geopolitical conflict situations in regions, political decisions on the international trade	Port Operations' disruptions, port operations' delays, port congestions, supply chain bottle necks, port closures
2. Technological disruptions	Automatization, digitalization, integration of artificial intelligence, internet of things and sensorial systems	Workforces transition in skilling and upskilling, cybersecurity threats, infrastructure adaptation, significance investment in infrastructure adaptation, lost of competitiveness, disruptions in functionality and closures if does not meet general digitization conditions
3. Environmental sustainability issues	Increasing stringent environmental regulations, increasing stringent standards, reducing greenhouse gasses emission, mitigating pollution, protecting innovative technologies for marine ecosystems, new conceptions (it was mentioned "green port," "blue economy" conceptions), sustainable human behaviour, sustainable consuming culture	Significant investments, lack of knowledge for implementation of new regulations, and new unknown and not finally discussed conceptions, demand for new methodologies to measure impact and progress
4. Infrastructure constraints	Outdated and inadequate infrastructure, technological infrastructural innovations for the green transition projects, new projects and new development strategies which require additional resources especially time	Hindered port capacity, stopped processes, limited operational efficiency, lost competitiveness
5. Collaborations among the POE actors	Lack of coordination operations among port companies, lack managerial capacities of PA, lack coordination of POE, lack of managerial knowledge in collaborative competitiveness inside POE, not effective business models in POE companies	Lost operational efficiency, lost added value creation, lost maritime attractiveness in global supply chain, lost competitiveness
6. Trade volatility and economic uncertainty	Fluctuations in global trade patterns, economic downturns	Lost markets, lost competitiveness
7. Human capital and talent management	Lack of skilled workforce, cultural components, organizational culture, and priorities	Lack level of technological innovations, stopped processes of green transition or blue economy development projects
8. Cybersecurity risks	Increasing vulnerability to cyber-attacks, data branches, ransomware attacks, increasing demand cyber security innovation for data safety and security	POE's systems disruption, POE disruption, specific and global supply chain disruptions
9. POE governance	Port governance frameworks vary widely across regions	Regulatory inconsistencies, challenges for port operators

green port, failing to cultivate such a culture risks stalling innovation and losing economic competitiveness" (S2EL7).

In summary, most challenges are associated with port organizational development in automation and technological innovation. Ineffective management in these areas can have severe negative impacts, from loss of competitiveness to the potential closure of the entire POE. Some geopolitical factors are highly unpredictable and challenging to manage; thus, strengthening resilience management in other areas where preparedness can positively affect both external and internal uncertainties is essential.

In concluding the analysis of the focus group interviews and based on the categorization and classification of challenges and their impacts as per the research methodology, a statistical analysis was conducted. This analysis identified dominant factors across different categories, which are presented in the Table 4. It could be seen that the most frequently mentioned challenges originate from the technological sphere, reinforcing the earlier assertion that digitalization and automation pose significant challenges

to the POE. These findings underscore the notion that a substantial portion of challenges, when classified according to organizational resilience components, fall under the category of management. This observation supports the assumption that inadequate managerial capabilities and a lack of coordinated collaborative actions can adversely affect the functionality of the POE. These classified challenges, by their negative impact, primarily affect beneficiary parameters but also various types of port disruptions.

In summarizing the analysis of challenges for POE resilience and their potential negative impacts, it can be concluded that managerial interventions aimed at enhancing resilience in these areas should be analysed from a governmental perspective. This involves examining the interplay between governance patterns, ecosystem resilience, and managerial practices to determine their effectiveness under different circumstances. Exploring such interactions can guide the development of strategic interventions tailored to bolster resilience across diverse fields and scenarios within the POE.

Table 4. Frequency of challenges and impacts according to the results of focus group discussion on the identification of challenges in POE resilience framework in contemporary environment and their possible result on POE resilience

Classification by PESTEL, summarized frequency 63, length of interval 4, number of categories k = 6					
Challenges (PESTEL)	≤4	(4;8]	(8;12]	(12;16]	(16;20]
Political	4				
Legislative		6			
Social		9			
Environmental		9			
Economical			15		
Technological					20

Classification by components of POE resilience, summarized frequency 63, length of interval 5, number of categories k = 4				
Challenges (Resilience)	≤9	(9;14]	(14;19]	(19;24]
Culture & behaviour	9			
Human Resources	11			
Critical infrastructure & technologies		19		
Management			24	

Classification by negative impact, summarized frequency 35, length of interval 5, number of categories k = 3			
Negative Impact	≤4	(4;9]	(9;14]	(14;19]
Stopped transitions	4			
Disruptions		12		
Economical loses			19	

4.2. Interplay of POE governance patterns and POE resilience framework

The responses regarding the interdependence of challenges, as presented in Table 1, and POE governance patterns indicate a strong relationship between POE resilience and governance structures. According to the focus group experts, a strong relationship exists between the resilience of POE and its governance patterns. Experts particularly highlighted that POE governance should be flexible, with transparent and accountable decision-making processes and agile, mentoring leadership. All experts concurred that the governance patterns of the POE significantly impact its resilience to the uncertainties. By promoting collaboration, innovation, transparency, and accountability, effective governance frameworks can enhance POE resilience and contribute to long-term sustainability and competitiveness in the maritime industry. A brief review of the justification factors for this relationship is presented below, as summarized from the focus group discussions:

- global supply chain disruptions: POE governance patterns are crucial in coordinating responses to supply chain disruptions. Effective governance frameworks facilitate collaboration among port stakeholders, including port authorities, terminal operators, shipping lines, and government agencies, enabling the development of contingency plans, information sharing, and coordinated measures to mitigate disruptions. Port authorities should serve as initiators and coordinators of these processes at the POE governance level;
- technological disruptions: POE governance patterns determine the extent to which ports embrace technological innovations and adapt to digital disruptions. Proactive governance models that prioritize innovation and collaboration create a conducive environment for technology adoption, investment, and knowledge sharing among port stakeholders;
- environmental sustainability and regulatory compliance: POE governance frameworks significantly influence the implementation of environmental sustainability initiatives within the POE. Ports governed by sustainability-oriented policies and regulations are more likely to invest in green technologies, adopt sustainable practices, and comply with environmental standards, thereby reducing their ecological footprint and enhancing environmental resilience;
- infrastructure constraints: governance patterns impact infrastructure investment decisions and project prioritization within the POE. Ports governed by transparent, accountable, and participatory decision-making processes are better equipped to address infrastructure constraints, secure funding for infrastructure projects, and optimize resource allocation to enhance infrastructure resilience. Enabling a concession policy to its maximum capacity

can improve the investment climate within the POE, attract more foreign investment for necessary infrastructure upgrades, and minimize port authority expenses;
- port congestion and capacity management: effective governance structures facilitate coordination and collaboration among port stakeholders to manage congestion and optimize capacity utilization. Ports governed by integrated, multi-stakeholder governance models can implement measures such as port community systems, slot booking systems, and coordinated berth scheduling to alleviate congestion and improve operational efficiency;
- trade volatility and economic uncertainty: POE governance patterns influence resilience against trade volatility and economic uncertainty. Ports governed by adaptive, responsive frameworks can quickly adjust strategies, diversify revenue streams, and implement risk management measures to mitigate economic fluctuations and maintain financial stability;
- human capital and talent management: governance patterns influence human capital development and talent management practices within the POE. Ports governed by inclusive, participatory models prioritize workforce development, skilling and reskilling initiatives, and talent retention strategies to address human capital challenges and build a skilled, resilient workforce;
- cybersecurity risks: governance patterns determine the prioritization of cybersecurity measures within the POE. Ports governed by proactive, collaborative frameworks establish cybersecurity protocols, conduct risk assessments, and invest in cybersecurity training to mitigate cyber threats and enhance cybersecurity resilience.

By summarising of these argues, the interdependence between POE governance patterns and resilience underscores the necessity for ports to implement proactive governance frameworks. These frameworks enable ports to effectively address various external and internal challenges, thereby enhancing their resilience across multiple dimensions such as technology adoption, environmental practices, and human resource management.

To remain competitive in the rapidly evolving maritime industry, ports must prioritize the alignment of governance patterns with resilience objectives. This alignment should focus on fostering collaboration, innovation, and strategic adaptability in response to global supply chain dynamics and emerging technological trends. Moreover, by strengthening cybersecurity measures and talent management practices, ports can safeguard against potential threats and build a robust, agile, and skilled workforce ready to face future challenges.

In conclusion, the thoughtful integration of governance patterns with resilience strategies is crucial for ensuring the continued growth and stability of POE within the global maritime landscape.

4.3. Constructing the system of managerial interventions for enhancement of POE resilience

Based on theoretical findings and on the establishing general effective governance patterns for the enhancement of POE's resilience it could be mentioned that managerial interventions for enhancing POE resilience can be implemented across different governance patterns. While the specific implementation methods may vary depending on the governance model, the overarching goal of enhancing resilience remains consistent.

Political uncertainties: by implementation of managerial interventions POE can effectively manage the resilience in response to national and international legislative issues in the external environment, ensuring compliance with legal requirements, safeguarding their interests, and promoting a favorable regulatory environment for port development and growth.

The Table 5 presents a matrix of managerial interventions designed to enhance the resilience of POE in response to various external uncertainties. Based on theoretical insights and general governance patterns, the

Table 5. Matrix of managerial interventions for the enhancement POE resilience by reacting to diverse external uncertainties constructed as the result of focus group discussion's analysis

POE resilience factors	Political	Economical	Social	Technological	Ecological	Legislative
Managerial capacities (Engagement)	Stakeholder engagement in diplomacy initiatives	Stakeholder engagement in economic and innovations initiatives	Community engagement	Engagement the professionals from digitalization and automation centres to the port development initiatives	Representatives of environmental agency engagement into the port development committees	Governance relations and advocacy
Managerial capacities (compliance)		Compliance with economic development strategies on regional, national, and international levels	Compliance traditions and cultural norms	Regulatory compliance, standard adoption, continuing monitoring	Compliance with environmental regulations and adoption to climate change	Compliance with management systems
Managerial capacities (diversification)	Diversification of trade routes and partnerships	Diversification of trade and revenue streams	Diversity and inclusion programs	Diversified technological suppliers and service providers	Diversified consuming	Diversified public policies, analysis and research partners
Managerial capacities (cooperation)		Strategic partnerships and alliances	Stakeholder collaboration	Collaborations with High Tech partners and startups in entrepreneurial clusters	Collaboration with communities for the ensuring sustainable consuming	Collaboration with industry stakeholders in venture
Managerial capacities (unpredicted events' management)	Risk assessment scenario planning	Risk management and contingency planning	Conflict resolution mechanisms	Cybersecurity measures	Risk management in the field of human reaction to transitions	Legal counsel and risk management
Managerial capacities (strategies)	Adoption of flexible operational strategies	Promotions of trade facilitation and investment attraction Dynamic pricing strategies	Strategies for coastal regions economic and sustainable development including citizens and communities	Data analytics and predictive modelling strategies AI and the newest technologies usage strategies	Strategies for the implementation's blue economy, green port, green transition models	Clear strategical vision and documents
Material resources and environment protection	Investments in technology and security infrastructures	Investments in infrastructure and technological innovations	Heritage conservation and environmental preservation through Sustainability and green initiatives	Investments in technological infrastructure Digital transformation initiatives	Habitat restoration and conservation Environmental impact assessment Water conservation and management Green transitions acceleration	Description, standardization of green transitions Sustainable development acceleration programmes

POE resilience factors	Political	Economical	Social	Technological	Ecological	Legislative
Human resources	Capacity building and training programs	Sustainable and environmentally responsible consuming initiatives, POE's members sustainable behaviour management	Maritime culture awareness training	Training and capacity building	Community engagement and education on sustainable consuming and sustainable behaviour	Capacity building and training
Social values and culture	Providing maritime culture initiatives	Sustainable consuming culture initiatives	Corporate social responsibility (CSR) initiatives Cultural sensitivity	Digital culture for be safe	Pollution prevention control measures and dissemination techniques	

matrix identifies specific interventions across different areas of governance – political, economic, social, technological, ecological, and legislative. These interventions aim to strengthen POE resilience by employing diverse management capacities, such as stakeholder engagement, compliance, diversification, cooperation, risk management, and strategic planning.

The focus group discussion's analysis highlights how these managerial capacities can be applied to manage risks and uncertainties effectively, ensuring legal compliance, fostering a favourable regulatory environment, and promoting sustainable development. The matrix serves as a practical framework to guide POE in adapting to and thriving amid evolving external conditions.

In conclusion, the proposed matrix of managerial interventions offers a structured approach to enhancing the resilience of POE in the face of diverse external uncertainties. By strategically applying various management capacities – such as engagement, compliance, diversification, cooperation, risk management, and strategic planning – POE can effectively navigate political, economic, social, technological, ecological, and legislative challenges. This framework provides a flexible yet comprehensive tool for developing robust governance practices that promote sustainability, compliance, and long-term growth, ensuring that POE remain adaptive and resilient in a constantly changing environment.

5. Conclusions

The literature review and analysis of previous research identified that external unpredictable conditions impact the maritime ecosystem, potentially leading to disruptions and closures. These developments can halt innovative initiatives and hinder transitions to more sustainable port operations. Together, these factors contribute to a loss of competitiveness due to decreased connectivity, resulting in reduced financial benefits and other economic losses. It was thus established that ensuring sufficient POE resilience is crucial, achievable via the theoretical model of organizational resilience.

Based on the theoretical resilience model, it was found that forming a framework of managerial interventions necessitates researching three key factors: challenges and impacts, governance patterns influencing resilience enhancement methodologies, and main possible managerial interventions. The structured interview agenda for the research was based on these types of questions.

The research analysis revealed that technological challenges dominate within the POE according to the PESTEL classification. However, in terms of organizational resilience components, managerial challenges exist within the ecosystem. This reality emphasizes the need to explore the relationship between technological challenges and the managerial context. It was found that while technological innovations and the adaptation to new technological solutions can pose challenges to resilience, they are also tools that enhance operational sustainability and resilience. Yet, some managerial weaknesses within and outside the ecosystem create this paradoxical situation.

This research constructed a robust conceptual model identifying key dimensions and determinants of POE resilience. By integrating components such as critical infrastructure, human resources, managerial capacities, and organizational culture, the model supports the notion that adaptive governance frameworks – characterized by flexible leadership methodology which leads transparency, inclusivity, and strategic foresight – are vital. These frameworks allow ports to systematically assess their capabilities and vulnerabilities, forming the foundation for targeted resilience-building initiatives.

Based on the focus group interviews, a framework was developed wherein critical managerial interventions were identified: engagement, diversification, ensuring compliance with national governance visions and strategies, and promoting social inclusion and responsibility. These interventions aim to enhance operational continuity and sustainability. Moreover, developing a consumption culture inside and outside the ecosystem is indicative of strengthening sustainable port operations and fostering coastal development with the communities of port cities and regions. These strategic objectives entail empowering

port authorities and stakeholders to implement adaptive strategies that anticipate and manage future challenges, thus ensuring the continued growth and stability of POE within the global maritime landscape.

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