

REVIEW

Open Access



Building resilience in port-cities: the role of open innovation and innovation ecosystems

Maria Rosilene Sabino^{1,3*}, Maria do Rosário Cabrita^{1,2}, Marcela Souto Castro^{3,4}, Ana Mendes³ and Tiago Pinho³

*Correspondence:

Maria Rosilene Sabino
mr.sabino@campus.fct.unl.pt
¹UNIDEMI, Department of
Mechanical and Industrial
Engineering, NOVA School of
Science and Technology, NOVA
University Lisbon,
2829-516 Caparica, Portugal
²Laboratório Associado de Sistemas
Inteligentes, LASI,
4800-058 Guimarães, Portugal
³RESILIENCE– Center for Regional
Resilience and Sustainability, Escola
Superior de Ciências Empresariais,
Instituto Politécnico de Setúbal,
Campus do IPS - Estefanilha,
2910-761 Setúbal, Portugal
⁴NECE - Research Centre for
Business Sciences, Universidade
Beira Interior (UBI), Rua Marquês
D'Ávila e Bolama, 6201-001 Covilhã,
Portugal

Abstract

The port industry plays a vital role in the global economy by enhancing supply chain connectivity and supporting international trade. In recent years, disruptive events such as economic crises, environmental challenges, and technological advancements have profoundly reshaped the dynamics of seaports and port towns. Port cities represent complex ecosystems that integrate logistical, economic, and social activities, acting as critical nodes in the global trade network. The process of leveraging internal and external knowledge, alliances, and partnerships to accelerate innovation and improve problem-solving capabilities is known as open innovation. Conversely, innovation ecosystems describe linked networks of stakeholders—including businesses, governments, academia, and civil society—that cooperate to drive technical innovations and sustainable solutions. Both approaches are practical approaches to address complex challenges, encouraging collaboration and co-creation of solutions. However, their application in port cities and their influence on organisational and urban resilience require further investigation. Through a semi-systematic literature review, this study identifies key trends, challenges and opportunities associated with open innovation and innovation ecosystem, highlighting their potential to enhance resilience in port city contexts. Findings suggest that structured and inclusive collaboration significantly enhances urban and organisational adaptability, particularly in response to climate change and digital transformation pressures. A future research agenda is proposed to further investigate the long-term impacts of collaborative innovation on resilience in port cities.

Keywords Port city, Open innovation, Innovation ecosystem, Resilience, Sustainability, Digital transformation, Seaport

1 Introduction

Seaports play a crucial role as drivers of the global and regional economy, facilitating supply chain connectivity and bolstering international trade. Their operations significantly influence the surrounding urban areas by fostering economic growth, generating employment, and attracting business opportunities [1]. However, port cities face increasing pressure to adapt to disruptions such as economic crises, climate change, and technological advancements, which affect both port infrastructure and urban development



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

[2]. These challenges necessitate innovative approaches to enhance resilience and ensure the long-term sustainability of port ecosystems.

As seaports and their adjacent urban areas become more interconnected, their exposure to environmental, economic, and technological disruptions grows [3]. Sustainability concerns related to increased maritime activities, energy consumption, and emissions are key challenges that require adaptive strategies [4]. Planning for resilience—the ability of port cities to anticipate, absorb, and recover from disruptions—has thus become a priority for both port authorities and policymakers [5].

Innovation is increasingly recognised as a strategic facilitator of resilience [4]. By promoting collaboration, adopting technological advancements, and developing adaptive policies, port cities can mitigate risks and enhance their capacity to withstand external shocks. However, the successful integration of innovation into resilience strategies requires structured mechanisms for stakeholder engagement, knowledge exchange, and institutional support [5].

Open Innovation (OI) and Innovation Ecosystem (IE) provide systematic frameworks for incorporating multiple actors and facilitating innovation within port cities. OI encourages collaborative problem-solving, leveraging external knowledge sources and partnerships to accelerate innovation processes [6]. Unlike conventional closed innovation models, this approach fosters co-creation among businesses, research institutions, policymakers, and communities, allowing for more adaptive and dynamic solutions to emerging challenges [7].

Conversely, IE provide the structural and institutional support necessary for innovation to thrive. These ecosystems cultivate an environment where firms and institutions can generate and implement innovative solutions that enhance the competitiveness and resilience of port cities [5]. Successful initiatives in Rotterdam and Valencia illustrate the importance of collaboration between the public and private sectors to foster innovation, efficiency, and sustainability [8].

Despite their distinct focuses, OI and IE are inherently interconnected:

- OI provides the collaborative mechanisms that fuel innovation, ensuring that knowledge exchange and partnership lead to meaningful advancements.
- IE establishes the governance structures and institutional support that allow innovations to be implemented and scaled effectively.

Together, they create a dynamic environment that supports long-term resilience in port cities.

While OI and IE are individually recognised for their potential to enhance resilience, there remains a lack of integration between these two frameworks in the context of port cities. Existing studies on OI in port environments primarily focus on efficiency gains, digitalisation, knowledge exchange, and stakeholder collaboration [4, 9–11], but they rarely explore its direct link to resilience-building in port city areas.

On the other hand, IE research in port cities examines capital interactions (social, human, industrial, and natural) [3, 8], governance mechanisms, and the role of startups [12]. However, there are gaps in understanding knowledge transfer among ecosystem participants [8, 13, 14]. Additionally, empirical evidence on how these ecosystems contribute to economic, environmental, and organizational resilience remains scarce [11, 15].

Furthermore, despite the increasing relevance of resilience in port city research, existing studies fail to provide a unified framework that connects:

- OI strategies for knowledge exchange and stakeholder engagement, and
- IE structures that facilitate policy implementation, institutional collaboration, and long-term adaptation.

The absence of a comprehensive framework hinders the development of effective innovation-driven resilience strategies that could better equip port cities to manage uncertainty and systemic disruptions [8].

To address this gap, this study seeks to answer the following main research question: How can OI and IE enhance organisational and urban resilience in port cities? This central question gives rise to several sub-questions:

1. What are the key trends shaping the adoption of OI and IE in port-city contexts?
2. What are the critical challenges port cities face in implementing collaborative innovation approaches?
3. What strategic opportunities can port cities leverage through collaborative innovation practices to enhance resilience?
4. Which practical implementation paths derived from the literature can effectively address identified barriers and leverage opportunities for innovation and resilience?

Through a semi-systematic literature review, this study aims to identify these trends, challenges, and opportunities, providing a structured synthesis of the interplay among OI, IE, and resilience. It further develops practical implementation paths tailored specifically for stakeholders within port-city ecosystems.

This review provides both theoretical insights and practical recommendations for port authorities, policymakers, and industry stakeholders. By integrating OI and IE into a resilience framework, this research contributes to sustainable, adaptive, and innovation-driven strategies for port city environments.

This paper is structured as follows: Sect. 2 outlines the methodology, including the methodological approach (2.1) and article selection strategy (2.2). Section 3 develops the theoretical framework, covering Open Innovation (3.1), Innovation Ecosystem (3.2), Urban and Organisational Resilience (3.3), and the relationship between ports, industries, and cities (3.4). Section 4 presents bibliometric results, analysing subject areas (4.1), authorship patterns (4.2), and keyword co-occurrence networks (4.3). Section 5 includes a narrative analysis and discussions on the applications of Open Innovation and Innovation Ecosystems in urban resilience (5.1), trends, challenges and opportunities in this field (5.2, 5.3), and practical pathways for implementation (5.4), along with a research agenda for collaborative innovation (5.5). Lastly, Sect. 6 summarises the key findings and conclusions.

2 Theoretical framework

This section synthesises the theoretical elements of OI, IE, and resilience, establishing the key concepts and constructs that support the analysis and interpretation of the findings. In this study, “external” refers to the actors of knowledge sources outside the core organisational boundaries of the port authority, including startups, academic

institutions, suppliers, civil society, and government bodies at regional, national, and international levels.

2.1 Open innovation

The concept of OI was introduced by Chesbrough [6] as a response to the limitations of the traditional, closed model of innovation that depended solely on internal research and development efforts. OI advocates for a paradigm shift, endorsing the incorporation of external knowledge flows, collaborative partnerships, and cooperative arrangements into the organisational innovation processes. This approach posits that innovation transcends the limitations of individual entities, emerging instead from the dynamic interplay among various stakeholders, such as firms, universities, governments, and communities.

OI is generally categorised into three distinct modalities: inbound innovation, which refers to the integration of external knowledge into internal processes; outbound innovation, which involves externalising unused ideas or technologies; and coupled innovation, which combines both inbound and outbound processes through co-creation with partners [7].

This model allows organisations to access broader knowledge networks, reduce risk, and accelerate problem-solving.

In the context of port cities, OI assumes a particularly strategic role. Port cities operate as intricate systems wherein a multitude of stakeholders coexist—namely, port authorities, logistics firms, technology providers, public agencies, startups, and local communities [8]. OI provides a framework for aligning these actors through shared innovation initiatives. It enables the development of solutions that address logistical constraints, promote sustainability, enhance digital infrastructure, and strengthen governance structures.

2.2 Innovation ecosystem

The concept of IE provides a framework to understand how innovation emerges and scales within a complex network of interconnected actors and institutions [16]. In contrast to linear innovation models, IE highlights the co-evolution of technologies, capabilities, and relationships across organisational and societal levels. It emphasises that innovation arises not from isolated efforts but from dynamic interactions among stakeholders who provide complementary assets and knowledge.

In the context of port cities, IE offers a critical framework for comprehending and managing the intricacies of innovation processes. Ports function as multi-actor systems, where value creation relies on both technological progress and coordination among actors with varying objectives, capabilities, and resources [8]. An IE approach facilitates the mapping and orchestration of relationships, promoting collaboration across conventional sectoral boundaries [15].

Furthermore, IE enables the mobilisation of multiple forms of capital—human, social, financial, natural, and technological capital—which are essential for resilient and sustainable port transformation [3]. A critical function of IE is to provide institutional stability and strategic alignment, ensuring that innovation efforts form part of a coherent long-term vision, rather than remaining isolated [17].

Literature frequently addresses IE in abstract or normative terms [16], which results in limited practical application within maritime and urban port contexts. A gap persists in understanding how IE operates in port cities, particularly concerning resilience-building and sustainability transitions.

2.3 Urban and organisational resilience

The concept of resilience has increasingly gained attention across various disciplines, including ecology, urban studies, organisational science, and complex systems theory. Resilience fundamentally denotes a system's ability to withstand disturbances, adjust to evolving conditions, and undergo transformation in reaction to shocks while maintaining its core functions and structure [18, 19]. In port cities, where logistical, environmental, technological, and social systems are intricately interconnected, resilience is essential for ensuring long-term sustainability and competitiveness [20].

In urban studies, resilience refers to the capacity of cities to endure and recover from environmental threats (e.g., sea level rise, storms), socio-economic crises (e.g., pandemics, trade disruptions), and infrastructure failures [21, 22].

In organisational science, resilience involves maintaining continuity under stress, adapting to uncertainty, and learning from crisis [23, 24]. In port environments, organisational resilience applies to port authorities, terminal operators, logistics firms, and other key stakeholders that must remain agile in the face of increasing complexity [25].

Resilience is commonly characterised by three interrelated dimensions [26]:

- *Adaptive capacity* The ability to respond and adjust proactively to change.
- *Robustness* The strength and redundancy of systems to withstand shocks without collapsing.
- *Transformability* The capacity to fundamentally change systems and practices when existing structures are no longer viable.

Port cities, in particular, can be understood as hybrid socio-technical systems, shaped by the continuous interaction between infrastructure networks, economic flows, governance institutions, and urban communities [2].

Thus, building resilience in port cities requires technical solutions alongside governance mechanisms, collaborative innovation strategies, and institutional arrangements that foster agility, continuous learning, and cross-sector coordination [4]. This systemic perspective is particularly relevant in complex environments such as port ecosystems, where urban and logistical functions intersect, and resilience must be cultivated at multiple levels [14]. The following sub-sections will examine how this multidimensional perspective is reflected in the dynamics of port-city interactions, where sustainable innovation and governance play critical roles in shaping adaptive capacity and long-term resilience.

2.4 The symbiotic relationship between ports, adjacent industries, and cities

The relationship between ports, adjacent industries, and cities is deeply interdependent, forming a complex system of mutual influence shaped by economic, spatial, environmental, technological, and institutional dynamics [12]. Historically, seaports have acted as engines of economic growth, generating employment, attracting businesses, and enhancing regional competitiveness [20]. This interdependence is visible in how seaports

attract logistics companies, insurers, legal services, industries, import–export houses, and other service providers, which in turn stimulate the development of surrounding areas [27]. Technological advancements, often incubated or implemented within port operations, further amplify this effect by fostering innovation in logistics, automation, digital connectivity, and supply chain optimisation [28].

In turn, port cities and their surrounding regions provide a skilled workforce, institutional infrastructure, and support services essential to sustaining port operations and driving continuous innovation [29]. This reciprocal relationship reinforces the strategic relevance of ports in global trade networks and highlights the importance of coordinated development between port functions and urban systems [12].

Spatial and functional integration between ports and cities presents both challenges and opportunities. In established or historic port cities, the large-scale industrial areas required for port activities can often create tensions with urban land use, mainly where residential, commercial, and recreational interests overlap or compete for space [27]. Conversely, in newly developed port zones, there is potential for improved spatial planning strategies to mitigate such conflicts [15].

Nevertheless, such friction has also catalysed innovation, with many cities revitalising former industrial and waterfront areas into hubs for technology, tourism, and creative industries [12, 27]. For instance, cities like Rotterdam and Barcelona have integrated cultural spaces, startups, and public infrastructure while preserving their maritime heritage [8, 30].

From an environmental and social perspective, the symbiotic nature of the port-city relationship also demands a balanced approach. Port activities inevitably impact urban environments, leading to issues such as noise, emissions, and congestion [2]. Therefore, environmental sustainability and social responsibility are essential pillars for the long-term resilience of port cities [31]. Sustainable port development includes the integration of low-carbon technologies, the revitalisation of waterfront zones, and the implementation of digital tools to improve resource efficiency—all of which contribute to minimising ecological impact and enhancing livability [32].

Effective governance plays a crucial role in managing the complexity of these relationships. Collaborative governance frameworks that involve port authorities, municipal governments, private firms, and civil society are increasingly seen as necessary for aligning economic development with social and environmental goals [8]. By fostering shared value creation, such models allow ports and cities to pursue competitiveness while simultaneously enhancing resilience, inclusiveness, and well-being [33].

This multifaceted interconnection between ports, industry, and cities forms the foundation for sustainable innovation and long-term development in port ecosystems. Rather than operating in isolation, these systems evolve through feedback loops that connect economic activity, technological advancement, urban transformation, and institutional collaboration. As port cities face increasingly complex demands, from environmental regulations to digitalisation [30], designing integrated strategies that align port operations with urban planning and sustainable innovation agendas becomes essential [33]. Leveraging an OI process among diverse stakeholders allows port ecosystems to maintain competitiveness and create shared value and long-term transformation [34, 35].

3 Methodology

This section aims to describe how the review was conducted, focusing on transparency and replication.

3.1 Methodological approach and tools

The study employed a semi-systematic literature review to investigate the integration of OI, IE and resilience within the seaport and port city. A semi-systematic review is a type of literature review that combines elements of both systematic and narrative reviews [36]. It aims to provide a comprehensive and rigorous synthesis of the existing literature on a specific topic while allowing for some flexibility in the review process [37].

A semi-systematic review is justified as it provides a flexible, comprehensive, and practical approach to synthesise literature, identifying gaps, and contributing to theoretical advancements in complex research areas [38]. This approach allows addressing focused research questions while accommodating a wide range of diverse literature, making it particularly useful for exploring connections and integrating concepts [36].

Examination of the articles was conducted in two phases:

- *Bibliometrics* Identification of the most frequently referenced authors, institutions, and keywords, creating clusters with VOSviewer (version 1.6.20).
- *Narrative* A qualitative synthesis of core topics, emphasising the identification of interconnections among OI, IE, and resilience.

The bibliometric analysis provided a quantitative overview of the research landscape, while the narrative analysis delved deeper into the qualitative aspects of the articles. By combining these two approaches, a comprehensive understanding of the topic was achieved, highlighting both the quantitative and qualitative dimensions of OI, IE, and resilience.

In conclusion, a semi-systematic review allows the integration of relevant studies, even if not all of them are directly related or use the same terminology. It provides a comprehensive overview of the current state of research in this area.

3.2 Article selection strategy

A systematic article selection process was conducted using the Scopus database for its comprehensive coverage and high-quality indexing of peer-reviewed content.

The primary search strategy aimed to retrieve studies that examine open innovation, innovation ecosystems, and value creation in port-related contexts. To achieve this, the search focused on articles containing key terms such as “open innovation,” “value creation,” and “innovation ecosystem” in their titles, abstracts, or keywords. These terms were combined with “port city,” “seaport,” and “maritime” to ensure relevance to the maritime and port ecosystem.

The inclusion criteria for this phase were:

- *Publication period* Articles published between 2015 and 2024 to ensure recent and relevant contributions.
- *Source type* Only peer-reviewed journal articles and conference papers were included to maintain academic rigor.
- *Language* Only articles published in English were considered to ensure accessibility to the broader research community.

The exclusion criteria applied to eliminate studies from unrelated disciplines included:

- Subject areas such as biochemistry, materials science, arts, agriculture, earth sciences, and nursing, as they are not directly related to the scope of this research.
- Works that go beyond the thematic focus (e.g., unrelated to port city or seaport).

This first search resulted in 43 articles, which were subsequently reviewed for thematic alignment and methodological rigour.

To further assess the presence of sustainability, resilience, and crisis management in the selected literature, a secondary search phase was conducted using additional keywords such as “sustainability,” “resilience,” and “crisis management”. This step aimed to identify studies that explicitly address adaptive strategies and long-term resilience in port ecosystems. Notably, all 19 articles identified through this secondary search were already part of the initial collection of 43, thereby confirming the presence and integration of these themes within the primary dataset.

This consolidated set of 43 articles was subsequently exported in CSV format for detailed bibliometric and keyword analyses. An initial screening of titles and abstracts revealed that among these articles, only eight explicitly employed the term ‘open innovation’, whereas eleven focused directly on ‘innovation ecosystems’. However, a broader thematic examination indicated that 26 of the selected studies extensively discussed value-creation mechanisms within multi-actor environments, and a further eleven explicitly adopted terminologies and frameworks aligned with collaborative innovation practices. This analysis resulted in a final sample of 37 articles.

Given the terminological nuances identified within the literature, it is pertinent to clarify the conceptual framing adopted herein. Although this study primarily employs the theoretical lenses of OI and IE, the term ‘collaborative innovation’ is occasionally adopted as an operational proxy for practices closely related to OI. This is particularly appropriate in contexts where multi-stakeholder engagement, knowledge exchange, and ecosystem-based approaches are emphasised. Such terminological flexibility reflects the inherent heterogeneity of this research domain while preserving consistency with the theoretical foundations of OI and its relevance to fostering resilience in port-city environments.

The complete selection process is detailed in Table 1.

4 Bibliometric results and discussion

To support the conceptual framework discussed earlier, this section presents the bibliometric results of the semi-systematic literature review focused on OI, IE, and resilience in port ecosystems. The aim is to identify thematic patterns, disciplinary trends, and research gaps relevant to this study.

4.1 Subject areas analysis

To provide an overview of the disciplinary scope of the selected literature, this subsection presents the distribution of the 37 academic documents included in the final sample, according to the subject areas, as indexed in the Scopus database. As shown in Fig. 1, the Social Sciences represent the largest share (25%), followed by Business, Management and Accounting and Engineering, each with 14%. Other relevant subject areas include Environmental Science (13%), Energy (11%), and Computer Science (11%). Smaller

Table 1 Overview of the article selection process

Stage	Description	Number of articles
Initial Search	Results from Scopus using keywords related to OI, IE, and port contexts	76
After Year Filter (2015–2024)	Articles published within the designated timeframe	72
After Subject Area Exclusion	Exclusion of non-relevant subject areas (e.g., Chemical Engineering, Materials Science, Agricultural and Biological Sciences, Mathematics, Earth and Planetary Sciences, Arts and Humanities)	58
After the language filter	Limited to articles published in English	58
After the document type filter	Inclusion of only peer-reviewed journal articles and conference papers	43
Cross-check on resilience and sustainability keywords	Secondary verification using keywords “sustainability,” “resilience,” and “crisis management” confirmed all 19 identified articles were already included within the existing 43 articles	43
Title and abstracts screening	Removal of studies not aligned with the research scope based on title and abstract review	37
Final dataset	Final dataset of selected articles for bibliometric and thematic analysis	37

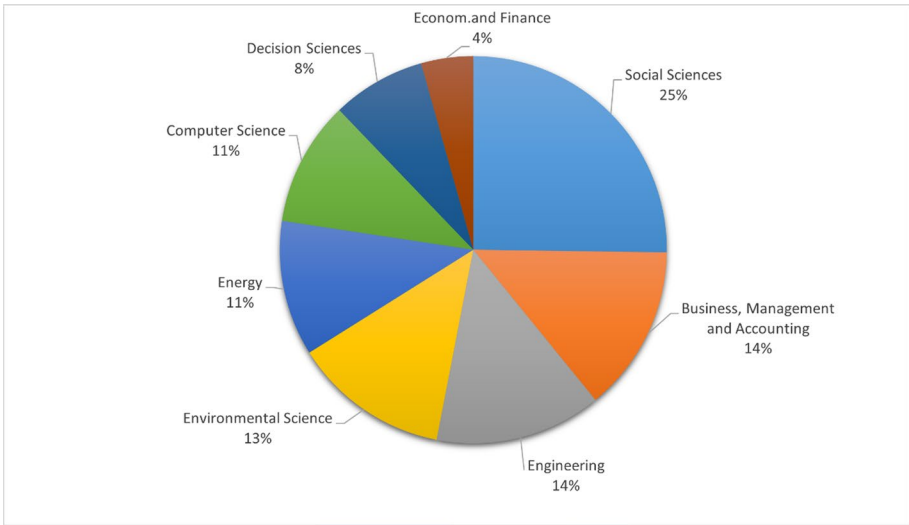


Fig. 1 Subject areas

proportions are represented by Decision Sciences (8%) and Economics and Econometrics (4%).

This distribution reflects the interdisciplinary nature of research on OI, IE, and resilience in port contexts. The predominance of Social Sciences and Business-related fields highlights a strong emphasis on institutional change, governance, and stakeholder dynamics, which are central to implementing innovation strategies in port ecosystems. In contrast, the contributions from Engineering, Environmental Science and Energy suggest that technological advancement, digitalisation, and sustainability transitions are also well represented in the literature. These fields contribute technical solutions, such as smart port systems, energy-efficient infrastructure, and automation, that support the broader transformation of port operations.

The presence of both technical and socio-economic domains underscores the need for integrative approaches that combine technical, organisational, and policy-oriented perspectives. Innovation and resilience in port ecosystems cannot be addressed from

a single disciplinary lens but rather demand a holistic framework understanding that bridges social, environmental, and technological dimensions.

4.2 Authors' analysis

To identify the most influential contributors in the field of OI, IE, and resilience in port ecosystems, a citation-based author analysis was conducted using data extracted from the Scopus database. The analysis considered all authors from the 37 selected documents and compiled total citation counts as of February 2025, using Scopus-indexed citation metrics.

Figure 2 presents the top 20 most-cited authors. Leading the list is Aiello G., followed by Giallanza A. and Mascarella G., each with citation counts above 50. Other prominent authors include Hermann R.R., Jugie J-H., McKelvey M., and Slack B., whose contributions are often cited in the context of maritime sustainability, digital transformation, or innovation policy in port-related environments.

This analysis helps highlight which authors have shaped the intellectual foundations of the field and whose work continues to inform the academic discourse. However, it is essential to note that high citation counts do not necessarily reflect conceptual integration across themes. While several widely cited authors have contributed to innovation and sustainability in the seaport field, few explicitly address OI, IE, or resilience, and no author integrates these concepts. This finding reinforces the fragmentation identified in the literature and supports the argument for a more integrative research agenda.

4.3 Keyword co-occurrence analysis

The bibliometric data used for the author keyword co-occurrence analyses were obtained from the Scopus database, using a structured search query as described in Sect. 2.2. A total of 37 peer-reviewed documents, published between 2015 and 2024, were exported in.csv format and analysed in VOSviewer (v1.6.20). The metadata extracted included authors, affiliations, keywords, citations, and abstracts.

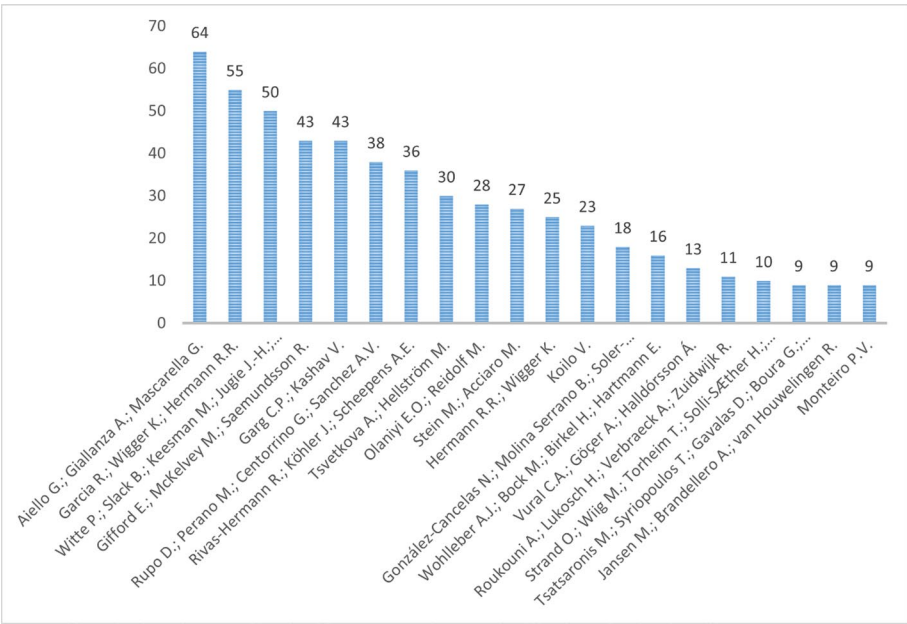


Fig. 2 Most cited authors

The dataset included 191 keywords, extracted from the 37 articles selected through the database. For this analysis, only keywords with a minimum of two occurrences were considered relevant for network construction. Based on this threshold, 21 keywords met the inclusion criteria.

Figure 3 shows the resulting co-occurrence network. The total strength of co-occurrence links was calculated for each keyword, measuring how frequently a given term appeared together with others across the dataset. Notably, 19 of the 21 keywords formed a connected cluster, indicating a significant degree of thematic convergence among the studies analysed.

Key terms with the most substantial co-occurrence linkages include: OI, IE, sustainability, value creation, digitalisation, business models, knowledge management, logistics, and eco-innovation.

The prominence of OI and IE confirms their centrality to the academic discourse in this domain. Their direct connections to terms like value creation, digitalisation, and sustainability highlight the multidimensional role innovation plays in addressing contemporary challenges within port ecosystems. These thematic linkages also reflect the growing interest in integrating technological, environmental, and business model innovations.

Interestingly, concepts such as corporate social responsibility and eco-innovation appeared in peripheral clusters, suggesting emerging subtopics that, while not yet fully integrated into the core literature, are gaining visibility and may shape future research agendas.

The co-occurrence analysis underscores the interdisciplinary and interconnected nature of current research. It also reinforces the need for integrated conceptual frameworks that bridge OI practices, ecosystem dynamics, and resilience outcomes in the sea-port and port-city context.

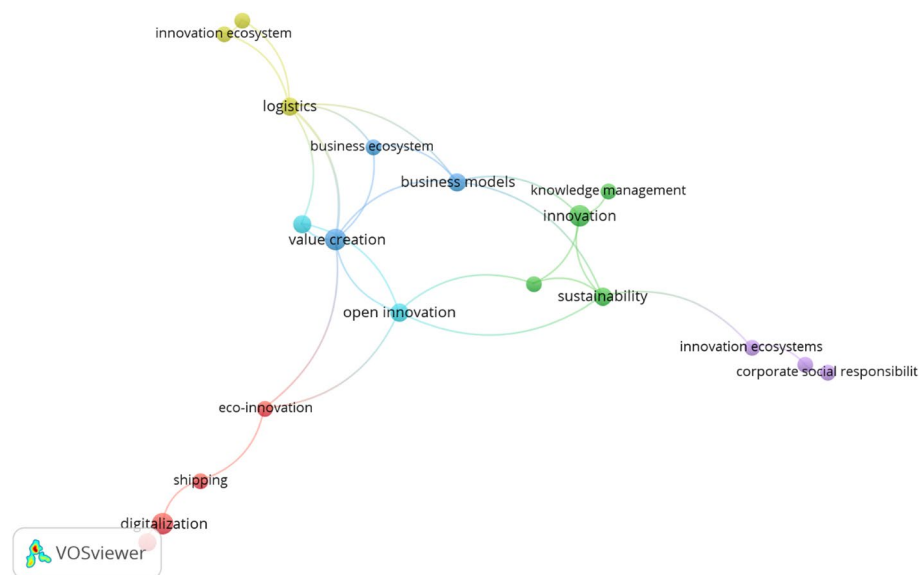


Fig. 3 Co-occurrence network of author keywords

5 Narrative analysis and discussion

The previous bibliometric analysis (Sect. 4) provided a foundational mapping of the key disciplinary areas, influential authors, and thematic patterns identified in the literature on OI, IE, and resilience in port cities. It highlighted central themes like sustainability, digitalisation, knowledge management, and value creation, emphasising the interconnections in the studied domain. This section builds on those insights with a narrative synthesis that critically examines the relationship between OI, IE and urban resilience in port cities. The discussion addresses research gaps, integrates theoretical perspectives, and proposes a coherent research agenda for future studies.

5.1 Application of open innovation and innovation ecosystem approaches in urban resilience

The application of OI and IE approaches to urban resilience offers strategic pathways for addressing the multifaceted challenges that modern port cities face. By promoting collaboration among diverse stakeholders, these frameworks enhance adaptive capacity against challenges such as climate change, social inequities, and sustainability issues. OI encourages creativity and co-creation through inclusive engagement, while IE ensures the institutional and structural coordination necessary for implementing innovation at scale.

One notable example is Rotterdam's Makers District, where bottom-up innovation integrates creative industries and the maker movement. These grassroots initiatives leverage local knowledge to repurpose urban spaces and develop community-driven solutions, reinforcing urban resilience [27].

IEs support resilience by aligning a constantly evolving set of actors and resources. This dynamic is crucial for integrating multiple perspectives into local problem-solving. Comparative cases such as Rotterdam and Valencia demonstrate how cross-sector collaboration can enhance resilience planning and improve a city's ability to adapt to uncertainty [8, 34].

The value co-creation paradigm is also central to these approaches. In the TESEO I project, for instance, collaboration among stakeholders in an Italian maritime cluster resulted in a sustainable vessel prototype tailored to community and environmental needs [11]. Such experiences show that innovation embedded in local ecosystems can drive both technological and social transformation.

Specifically, the application of OI and IE fosters:

- *Enhanced knowledge sharing* by enabling the exchange of expertise across institutions, industries, and communities [15];
- *Technological advancements* through the adoption of digital tools and resilient infrastructure, particularly relevant in the context of smart ports [9];
- *Economic and social resilience* by strengthening partnerships among firms, academia, and society to navigate disruptions [13];
- *Environmental sustainability* by advancing eco-innovation strategies and reducing environmental impact [13].

Policy and governance also play a crucial role in enabling these frameworks. Cross-sector platforms created by policymakers can support open collaboration, helping cities design more adaptive and integrative responses to urban challenges [12]. Moreover, the

openness of innovation processes facilitates risk mitigation and proactive adaptation by leveraging distributed knowledge and resources [14, 27].

By embedding OI and IE into urban development and resilience planning, port ecosystems can evolve into dynamic, responsive, and inclusive innovation environments—better equipped to anticipate and respond to emerging disruptions.

5.2 Trends shaping collaborative innovation

Urban resilience is increasingly influenced by collaborative innovation frameworks that incorporate various disciplinary perspectives, technological advancements, and stakeholder collaborations. These approaches emphasise the increasing acknowledgement that enhancing urban resilience necessitates both technological solutions and systemic, social, and institutional innovations.

The trends, challenges, and opportunities were derived from a qualitative thematic analysis of the 37 selected articles. Each article was carefully reviewed to identify recurring themes, patterns, and insights related to OI and IE strategies in port cities. Through iterative reading and coding, key dimensions were categorised under three main headings: trends, challenges, and opportunities. This process involved grouping similar findings across different studies and mapping them against core concepts such as stakeholder engagement, digitalisation, sustainability, and governance. Main Trends of Collaborative Innovation Related to Urban Resilience.

The transformation of port cities into more resilient, adaptive, and sustainable ecosystems increasingly relies on the strategic application of OI and IE. Recent literature reflects a paradigm shift in how urban resilience is approached, moving beyond solely infrastructural or technical solutions towards collaborative, systemic, and integrative innovation models. Drawing upon a thematic analysis of the selected literature, this section synthesises the key trends emerging at the intersection of OI, IE, and resilience in port-city contexts.

1. Shift from Closed to OI

Numerous authors [9–11, 13, 29, 34] highlight the growing shift within the port sector and port cities towards OI practices, moving away from closed and hierarchical models. Organisations are increasingly seeking external knowledge to accelerate innovation, engaging in partnerships with universities, start-ups, R&D centres, and even competitors.

2. Digital transformation as an enabler of OI

Authors such as [28, 30, 32, 35] identify digitalisation as a central driver of OI. Digital platforms, blockchain, the Internet of Things (IoT), digital twins, and collaborative systems such as PortCDM and PCS are enabling the integration of systems and real-time data exchange among multiple stakeholders.

3. Evolution of innovation ecosystems

Authors like [8, 12, 15, 39], emphasise the formation and consolidation of IEs around ports. These systems bring together firms, port authorities, universities, creative hubs, and public policies to co-create value and foster sustainable solutions.

4. Collaborative governance and policy support

Authors such as [27, 40] underline the importance of collaborative governance and policy frameworks that encourage innovation. Initiatives such as hackathons, innovation districts (e.g., the Makers District), and start-up support policies demonstrate how institutional environments can facilitate OI practices.

5. Focus on sustainability and green innovation

There is a consensus [3, 13, 30] regarding the increasing integration of sustainability into innovation practices. Initiatives aimed at eco-innovation, emission reduction, and the adoption of renewable energy sources indicate a paradigm shift towards environmental resilience.

6. Integration of diverse forms of capital

Innovation in port ecosystems involves the mobilisation of multiple forms of capital—human, natural, social, creative, and industrial—whose orchestration is essential for generating integrated and contextually relevant solutions [3, 40].

7. Spatial and functional transformation

The integration of physical spaces (ports, industrial zones) with digital connectivity and urban functions (education, tourism, culture) also emerges as a trend [3, 29, 32], expanding the role of ports as dynamic centres of urban innovation.

The identification of these overarching trends demonstrates the increasing strategic alignment between OI, IEs, and urban resilience in port cities. However, despite these promising developments, the practical adoption of collaborative innovation approaches remains complex and fraught with specific barriers and constraints. The following section delves deeper into these complexities, systematically addressing both the critical challenges encountered and the corresponding opportunities that emerge within OI strategies aimed at strengthening urban resilience.

5.3 Challenges and corresponding opportunities

Port cities are increasingly recognised as laboratories for collaborative innovation strategies to achieve sustainable and resilient urban futures. However, despite the transformative potential of OI and IE, their implementation within port-city contexts faces a range of interrelated challenges. This section presents a synthesis of key challenges and corresponding opportunities drawn from the reviewed literature, structured thematically to enhance conceptual clarity and policy relevance. The insights, summarised in Table 2, form the analytical bridge to the next Sect. 5.4, which proposes a forward-looking research agenda grounded in this empirical synthesis.

1. Governance and regulatory complexity

Governance fragmentation and regulatory misalignment are consistently highlighted as critical impediments to collaborative innovation in a port city context. Authors such as [13, 14, 40] emphasise that outdated, fragmented, or restrictive regulatory frameworks impede the effective experimentation and scaling of innovative solutions, particularly in rapidly evolving fields such as digitalisation and sustainable urban development. Conversely, these authors suggest opportunities in developing flexible and adaptive regulatory frameworks, advocating for governance structures that proactively facilitate

Table 2 Key challenges and corresponding opportunities in collaborative innovation for urban resilience

Challenge	Opportunity	Supporting authors
1- Governance and regulatory complexity	Innovation-friendly governance and adaptive regulatory frameworks enhancing policy coherence	[8, 10, 14, 40]
2- Stakeholder Coordination, Trust and Communication	Enhanced coordination through multi-level stakeholder networks; trust-building via intermediaries and simulation tools	[9, 10, 13, 14, 30, 32, 40, 41]
3- Technological and infrastructural limitations	Integrated digital platforms and smart technologies (IoT, digital twins, blockchain); smart port-city synergies	[8, 10, 28, 30, 32]
4- Cultural and organisational resistance	Innovation hubs, start-up support, relational proximity	[8, 12, 30, 32]
5- Knowledge Management and Capacity gap	Structured academic-industry collaborations, joint education programmes, continuous learning platforms	[8, 10, 12, 13, 35]
6- Financial and resource constraints	Diversified and inclusive funding models including public–private partnerships (PPP) and international collaborations	[8, 9, 13, 14, 34, 40]
7- Social and Spatial Inclusion Challenges	Inclusive urban planning, community-led initiatives ensuring equitable distribution of innovation benefits	[3, 8, 27, 32, 40]
8- Scaling and Internationalisation	Scalable and transferable solutions through structured learning and international benchmarking	[8–10]

innovation rather than constrain it. The efficacy of foresight methods in policy alignment, emphasising proactive governance to mitigate regulatory inertia [41].

To overcome these challenges, practical strategies include establishing neutral coordinating bodies or innovation stewards to streamline governance processes, aligning regulatory practices with strategic innovation goals, and fostering adaptive governance through policy sandboxes and strategic planning [9, 13, 32].

2. Stakeholder coordination, trust, and communication

Stakeholder misalignment, communication gaps, and pervasive trust deficits present substantial barriers to collaborative innovation. According [9, 10, 13, 30] the diversity of stakeholders, ranging from public authorities to private enterprises and civil society organisations, introduces divergent interests and complicates cooperation. Trust deficits particularly exacerbate these issues, limiting the willingness of actors to share data and collaborate openly [10, 14, 35].

Opportunities arise from structured, multi-level engagement mechanisms involving various stakeholders. Coordinated partnerships facilitated by neutral intermediaries, such as innovation stewards and dedicated coordination bodies, create effective pathways for stakeholder alignment. Furthermore, participatory methods—such as simulation games, foresight methodologies, and collaborative digital platforms—enhance transparent communication while fostering mutual trust and understanding [14, 32, 35].

3. Technological and infrastructural limitations

Port cities often face technical difficulties related to legacy infrastructure and lack of digital interoperability. Outdated buildings, poor connectivity, and incompatible digital systems restrict integration and slow transformation [10, 28, 30]. The absence of universal data platforms and inadequate cybersecurity provisions adds further complexity to digitalisation efforts [28]. These issues are particularly acute in older port areas, where physical limitations and infrastructural decay hinder adaptive reuse strategies and limit innovative transformation [32].

The development of digital platforms and control towers are critical response to these issues [11, 32]. Integrated data-sharing systems boost operational efficiency and allow ports to adapt more flexibly to interruptions [30]. Digital twins, predictive analytics, and intelligent logistics systems provide concrete prospects to modernise port-city ecosystems [32].

4. Cultural and organisational resistance

Resistance to organisational change and entrenched institutional practices represent critical challenges, with authors such as [8, 12, 32] noting significant institutional inertia within traditional, hierarchical port management structures. The prevailing “provincial mentality” often restricts openness to new ideas and inhibits flexible experimentation.

Opportunities arise through fostering innovation-friendly organisational cultures via targeted capacity-building programmes, innovation hubs, accelerators, and incubation spaces. These interventions encourage cultural shifts, promote agility, and create environments conducive to innovation and adaptation [8, 30, 32].

5. Knowledge management and capacity gaps

Knowledge asymmetries, communication barriers, and limited technical or managerial capabilities among stakeholders represent substantial barriers. [8, 10, 35] underline the challenge of transferring tacit and explicit knowledge across diverse actors with differing languages, cultures, and expectations.

To bridge these gaps, structured collaborations between academia, industry, and local governments, such as joint training programmes, internships, and structured community-of-practice networks, can facilitate effective knowledge dissemination and enhance local capacities. Establishing digital knowledge-sharing platforms further strengthens continuous learning and knowledge integration [13, 35].

6. Financial and resource constraints

Resource limitations and fragmented funding strategies significantly constrain collaborative innovation efforts, as noted by [9, 13, 34, 40]. Smaller enterprises and start-ups face difficulties accessing adequate financial resources, hindering their ability to contribute meaningfully to IEs.

Strategic responses include developing hybrid and inclusive financing models such as public–private partnerships, co-investment platforms, and innovation grants. These approaches diversify funding sources, mitigate economic risks, and foster sustained stakeholder engagement in collaborative initiatives [8, 13, 34].

7. Social and spatial inclusion challenges

Urban redevelopment projects in port cities frequently risk exacerbating socio-economic inequalities, spatial fragmentation, and the marginalisation of historically disadvantaged communities. [3, 8, 32] emphasise these tensions, highlighting how innovation-driven regeneration can inadvertently lead to exclusionary outcomes.

To address these challenges, opportunities exist in inclusive planning frameworks, participatory governance mechanisms, and community-led initiatives. Practices such as urban seeding, adaptive reuse of existing spaces, and inclusive innovation districts ensure equitable benefits distribution and social cohesion [8, 27].

8. Scaling and transferability challenges

While localised innovation practices and pilot initiatives often demonstrate potential, scaling these innovations presents significant challenges. [8–10] highlight difficulties in institutionalising successful innovations and transferring them across different contexts and scales.

Participating in international innovation networks, structured learning processes, and iterative pilot projects with built-in feedback loops offers effective solutions for scaling innovations. These pathways facilitate benchmarking, adaptation, and knowledge dissemination across diverse urban contexts [8–10].

This integrated analysis synthesises key challenges and opportunities, supported by clear implementation pathways, and thus provides a robust conceptual foundation for advancing collaborative innovation strategies that enhance urban resilience within port cities.

These challenges and opportunities are synthesised in Table 2 below.

This consolidated overview serves as the foundation for the research agenda in Sect. 5.3, which aims to deepen theoretical understanding and offer applied directions to enhance the contribution of collaborative innovation to urban resilience.

5.4 Practical implementation paths

Building on the challenges and opportunities summarised in Sect. 5.3, this section describes practical implementation pathways tailored to address the structural, organisational and relational barriers present in port cities. These pathways are categorised thematically and based on empirical insights from the reviewed literature. While some of these practical steps originate from articles focused on the maritime sector and not explicitly addressed to port cities, they highlight how structured collaboration, clear goals, incentives, technology, and an inclusive and iterative process can lead to significant innovation, including urban resilience.

1. Establishing coordinating entities and shared governance mechanisms

One of the most consistent challenges identified relates to stakeholder misalignment and fragmented governance structures, which impede effective coordination and trust-building [29, 39, 40]. To overcome these barriers, cities should establish central coordinating bodies or innovation stewards tasked with orchestrating collaborative efforts across public, private, and civil society actors [8, 13]. These entities can serve as neutral facilitators, ensuring strategic alignment, dispute resolution, and knowledge circulation among participants.

This coordination is essential for managing the complexities of multi-tiered stakeholder ecosystems, where interests frequently diverge. Establishing governance frameworks that clearly define roles, responsibilities, and decision-making processes enhances institutional coherence and strengthens the perceived legitimacy and stability of IEs [10, 15].

2. Building social capital through structured collaboration

To mitigate the risks of bounded rationality and bounded reliability [29] and to address trust deficits [35], the deployment of social capital mechanisms is vital. These include structured activities for bridging disconnected actors, bonding pre-existing groups, and

protecting shared knowledge from misuse. Such mechanisms foster trust, legitimacy, and mutual understanding—key prerequisites for sustained collaboration in innovation processes [29, 32].

In practice, this may take the form of regular multi-stakeholder forums, co-creation labs, or community-of-practice networks that institutionalise horizontal collaboration. These structures help overcome fragmentation by enabling the convergence of diverse interests and facilitating common purpose in innovation planning.

3. Enabling flexible experimentation and adaptive innovation cycles

A key challenge across IEs in port cities is the resistance to change and rigidity of traditional organisational models [3, 29, 39]. To address this, fostering a culture of experimentation is essential. This involves creating living labs, pilot projects, and simulation environments where actors can test, fail, iterate, and adapt without severe consequences [14, 32].

Successful examples include the use of serious games and scenario simulations to engage stakeholders in role-playing complex urban challenges, promoting shared learning and cross-sector understanding [14]. Cities may also initiate small-scale pilots—such as temporary public space redesigns or smart logistics trials—that offer tangible spaces for testing collaborative governance and technological solutions in real-world settings [3, 9].

These approaches are particularly effective when paired with continuous monitoring and evaluation mechanisms, enabling strategies to evolve as urban conditions change. Embedding feedback loops into governance frameworks ensures responsiveness, learning, and long-term adaptability [8, 34].

4. Leveraging digital platforms for coordination and data sharing

Technological limitations and lack of digital interoperability remain major constraints in collaborative innovation [15, 28]. To overcome these barriers, the implementation of integrated digital infrastructures—such as urban control towers, real-time dashboards, and open data platforms—can greatly enhance information flow, transparency, and strategic decision-making [28, 32].

These platforms support cross-sector synchronisation by enabling different urban actors to monitor shared indicators, identify vulnerabilities, and mobilise coordinated responses to disruptions. Furthermore, they foster trust and institutional memory by ensuring traceability of decisions and providing equitable access to critical knowledge [10, 35].

Digital platforms also serve as key enablers for inclusive participation. By facilitating citizen engagement through mobile interfaces or online consultation portals, these tools help democratise innovation processes and ensure that marginalised voices are integrated into resilience strategies [27, 39].

5. Investing in human capital and capacity-building

A recurring challenge in port-city is the uneven distribution of knowledge and the lack of technical or managerial capacity among key stakeholders [8, 35, 40]. To overcome this, practical paths include the design and implementation of targeted education and

training programmes that equip local actors with the skills necessary to navigate collaborative environments and adopt emerging technologies [29, 39].

University-industry-government partnerships can foster project-based learning and applied research, engaging students and early-career professionals in real-world innovation challenges [35]. Urban innovation hubs, internships, and continuous professional development initiatives—particularly in the fields of data analytics, climate resilience, and stakeholder engagement—strengthen both individual and institutional adaptive capacity [3, 12].

Such investments also contribute to a culture of organisational learning, which is vital for maintaining innovation performance in dynamic and uncertain urban environments.

6. Ensuring financial sustainability and inclusive funding models

Resource constraints are a persistent barrier to sustained collaboration in IEs [15, 40]. Therefore, it is essential to establish hybrid financing models that combine public investment, private co-financing, and philanthropic or international support [9, 12]. Instruments such as innovation funds, public–private partnerships (PPPs), and municipal innovation grants can reduce risks and foster long-term commitment.

Practical strategies include the creation of co-investment platforms targeting specific urban resilience goals, such as sustainable mobility, energy transition, or climate adaptation. Cities can also adopt demand-driven support schemes, such as innovation vouchers or tax incentives, tailored to the needs of SMEs and grassroots initiatives [11, 12].

By diversifying funding sources and embedding resilience priorities into budgeting frameworks, cities can make innovation more inclusive and sustainable over time.

7. Aligning policies and governance structures

Fragmentation in policy agendas and governance arrangements often undermines collective innovation [10, 15, 28]. As a response, cities need to adopt flexible, cross-sectoral governance mechanisms that clearly define roles, responsibilities, and decision-making structures across multiple levels and sectors [13, 29].

Practical paths include the establishment of urban innovation councils, resilience task forces, or dedicated coordinating bodies that ensure vertical and horizontal policy coherence [8, 13]. These entities can oversee the alignment of urban innovation strategies with broader sustainability goals (e.g., the SDGs, Port Vision 2030) while facilitating stakeholder engagement and conflict resolution.

Moreover, regulatory frameworks must accommodate adaptive regulation, allowing pilot projects and experimental solutions to scale up without being hindered by outdated legal structures [10, 40]. Strategic alignment between innovation and resilience policies is crucial to avoid duplication, reduce institutional inertia, and deliver coherent urban transformation.

8. Scaling collaborative innovation through international networks and adaptive learning

One of the key opportunities identified across the literature is the potential to scale local innovations through structured learning processes and participation in international innovation networks [8, 27, 40]. Port cities that connect with transnational platforms can accelerate learning cycles, benchmark against peer cities, and access new sources of funding and expertise.

Table 3 Research agenda related to challenges and opportunities

Research priority	Source(s)	Related challenge(s)/opportunity(ies)
The Role of Focal Firms in IEs	[15, 29]	Governance fragmentation; Stakeholder coordination
Integration of Heterogeneous Knowledge Domains	[8, 35]	Knowledge asymmetries; Co-learning and education
Port-City Interface Dynamics	[3, 40]	Spatial inequality; Urban regeneration
Dimensions of Resilience in Urban Contexts	[11, 32]	Environmental, social, and institutional interdependencies
Collaborative Innovation for Value Creation	[13, 34]	Value co-creation; Policy and investment alignment
Overcoming Barriers to Innovation in Maritime Logistics	[10, 30]	Regulatory barriers; Resource constraints
Community Engagement and Local Interventions	[14, 27, 41]	Empowering marginalised actors; Participatory governance
Technological Integration for Urban Resilience	[9, 28]	Digital platforms; Adaptive infrastructure

Practical implementation paths include engagement in cross-border innovation alliances, participation in EU-funded projects or international living labs, and the creation of knowledge-sharing platforms for best practices in resilience and digital transformation [14, 15, 32].

To ensure long-term impact, collaborative innovation initiatives must embed feedback loops, continuous monitoring, and adaptation protocols [10, 11, 39]. This allows cities to refine their strategies in real time, responding to shifting socio-economic and environmental conditions.

Moreover, building institutional memory through documentation, evaluation, and dissemination of results is crucial to scaling what works. Strategies such as open repositories, shared dashboards, and resilience scorecards enable replication and transferability of successful models across different urban contexts [9, 35].

5.5 Proposed research agenda for open innovation in urban resilience

Building on the thematic synthesis of challenges, opportunities, and practical implementation paths in the previous section, this research agenda identifies key priorities for advancing the role of collaborative innovation in strengthening urban resilience. Each priority is derived from observed gaps and tensions in the literature and addresses both theoretical and applied dimensions (Table 3).

1. Strategic role of focal actors in innovation ecosystems

Building on [8, 29], future research should investigate the strategic coordination role played by focal actors (e.g., port authorities, innovation hubs, public agencies) in fragmented IEs. These actors are essential in orchestrating inter-organisational collaboration, balancing co-opetition dynamics, and fostering alignment among heterogeneous stakeholders [8, 29]. Understanding how these institutions manage social capital and mediate value creation is crucial for sustaining IEs and resilience outcomes.

2. Integrating heterogeneous knowledge and learning mechanisms

The integration of diverse forms of knowledge—technical, social, local, and experiential—remains a persistent challenge in port city innovation [28, 35, 39]. Research is needed to explore effective mechanisms for knowledge translation and exchange between actors with divergent rationalities and objectives [35, 39]. This includes

assessing the impact of structured intermediaries, simulation games [14], and educational partnerships in reducing knowledge asymmetries and promoting continuous learning across sectors.

3. Collaborative governance and policy co-alignment

Several studies [10, 15, 34] highlight governance fragmentation and policy misalignment as key inhibitors of collaborative innovation. Future research should examine how adaptive governance models and multi-level policy networks [9, 11] can foster regulatory coherence, experimentation, and dynamic coordination across urban and port systems. Studies could analyse how policy sandboxes, strategic visions (e.g., Port Vision 2030), and institutional intermediaries support innovation at the port-city interface.

4. Addressing social equity and spatial inclusion in innovation strategies

Urban regeneration often risks marginalising local communities [27, 39, 40]. Future research should focus on the social dimension of collaborative innovation, exploring how to reconcile innovation-led redevelopment with inclusive spatial planning and social equity goals. This includes evaluating participatory approaches such as Urban Seeding and inclusive platforms that ensure equitable access to the benefits of resilience-building initiatives.

5. Operationalising co-creation and value realisation mechanisms

While value co-creation is a recurring theme [3, 10, 13], few studies detail how it is operationalised in practice. Future research should investigate the mechanisms through which collaborative innovation leads to measurable value—economic, social, environmental—particularly in port city contexts. Emphasis should be placed on exploring trust-building routines, standardised co-creation processes, and the use of living labs as tools for iterative validation and scaling of solutions.

6. Technology integration for urban and port resilience

The literature points to the transformative potential of digital technologies [28, 30, 32] but also identifies gaps in technological interoperability, data sharing, and platform governance. Research should explore how integrated digital solutions—such as real-time control towers, open data platforms, and predictive analytics—can support collaborative decision-making while ensuring security, equity, and accountability across actors.

7. Measurement and evaluation of collaborative innovation outcomes

Several authors [12, 14, 35] advocate for systematic evaluation mechanisms to track the impact of collaborative innovation. Future studies should develop and validate indicators that measure outcomes across the six resilience dimensions [3]: social, spatial, institutional, environmental, technological, and economic. Particular attention should be given to how feedback loops and real-time performance tracking enhance learning and adaptive capacity.

8. Scaling and transferability of innovation practices

Practical implementation paths described in Sect. 5.4 reveal diverse pilots and experiments (e.g., PortXL, Makers District, serious games, digital platforms) [14, 27]. However, questions remain about their scalability, institutionalisation, and replicability. Future

research should explore conditions for successful diffusion of innovation practices, including the roles of policy frameworks, contextual adaptation, and international networks in promoting system-wide transformation.

This agenda outlines a multifaceted research pathway focused on strengthening the link between collaborative innovation and urban resilience. By explicitly connecting each research priority to the challenges and opportunities mapped in Sect. 5.3, this framework provides a coherent bridge between theory and practice, ensuring future studies are grounded in both empirical gaps and applied needs within port-city ecosystems.

6 Conclusion

This study investigated how OI and IE can collectively strengthen urban and organisational resilience in port cities. Through a semi-systematic literature review and a robust combination of bibliometric and thematic analyses, it was established that collaborative innovation approaches, embracing multi-stakeholder engagement, strategic governance alignment, and technological integration, are crucial to addressing the complex sustainability and resilience challenges facing contemporary port cities.

Key findings highlighted several interconnected trends: the evolution from closed to OI models, the accelerating role of digitalisation, the consolidation of IE, and an increasing emphasis on collaborative governance and sustainability initiatives. Despite these promising developments, substantial barriers remain, notably governance fragmentation, stakeholder coordination issues, technological limitations, organisational resistance, financial constraints, and inclusion challenges. Nonetheless, corresponding opportunities—such as creating coordinated governance structures, facilitating flexible experimentation, investing in digital platforms, and promoting inclusive engagement—offer viable strategies for overcoming these barriers.

To effectively apply these insights, the proposed implementation strategies include the establishment of innovation stewards, the enhancement of social capital through organized collaboration, and the promotion of adaptive learning through living labs and international networks. The comprehensive research agenda highlights the need for further exploration into areas such as the roles of key actors, mechanisms for knowledge integration, policy alignment, and the scalability of innovative practices.

Ultimately, by integrating collaborative innovation frameworks into resilience planning, this research not only extends theoretical understanding but provides policymakers and port city stakeholders with tangible strategies to foster sustainable, adaptive, and inclusive urban environments.

Future research should prioritise the development of cohesive models that incorporate these elements, fostering resilience and sustainable development in port cities. By addressing these challenges, the port cities can position themselves as leaders in adaptive innovation and global trade.

Author contributions

Maria Sabino: Conceptualization, Investigation, Writing—Original Draft. Maria do Rosário Cabrita: Writing—Review & Editing. Marcela Castro: Writing—Review & Editing. Tiago Pinho: Funding Acquisition. Ana Mendes: Project Administration.

Funding

Content produced within the scope of the Agenda “NEXUS—Pacto de Inovação—Transição Verde e Digital para Transportes, Logística e Mobilidade”, financed by the Portuguese Recovery and Resilience Plan (PRR), with no. C645112083-00000059 (investment project n.º 53).

Data availability

No datasets were generated or analysed during the current study.

Declarations**Ethics approval and consent to participate**

Not applicable.

Consent to publish

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

Received: 1 February 2025 / Accepted: 10 June 2025

Published online: 16 July 2025

References

1. Mudronja G, Jugović A, Škalamera-Alilović D. Seaports and economic growth: panel data analysis of EU port regions. *J Mar Sci Eng*. 2020;8(12):1017. <https://doi.org/10.3390/jmse8121017>.
2. Stein M, Acciaro M. Value creation through corporate sustainability in the port sector: a structured literature analysis. *Sustainability*. 2020;12(14):5504. <https://doi.org/10.3390/su12145504>.
3. Jansen M, Hein C. Port city symbiosis: introduction to the special issue. *Marit Econ Logist*. 2023;25(2):211–29. <https://doi.org/10.1057/s41278-023-00257-x>.
4. Hermann R, Wigger K. Eco-innovation drivers in value-creating networks: a case study of ship retrofitting services. *Sustainability*. 2017;9(5):733. <https://doi.org/10.3390/su9050733>.
5. Valionienė E, Plačienė B. Resilience of seaport ecosystem: theoretical approach and future research. In: *Transport Means - Proceedings of the International Conference, Kauno Technologijos Universitetas*; 2022. pp. 688–693. [Online]. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85144583389%26partnerID=40%26md5=e2327f6e7435bd7da4c7fcd8fc306f>
6. Chesbrough H. Open Innovation: the new imperative for creating and profiting from technology. *J Eng Technol Manag*. 2003; 21.
7. Chesbrough H, Bogers M. Explicating open innovation: clarifying an emerging paradigm for understanding innovation. Oxford University Press, no. *New Frontiers in Open Innovation*, pp. 3–28, Apr. 2014, Accessed: Mar 14, 2025. [Online].: <https://ssrn.com/abstract=2427233>
8. Mendes Constante J, de Langen PW, Furió Pruñonosa S. Innovation ecosystems in ports: a comparative analysis of Rotterdam and Valencia. *J Shipp Trade*. 2023. <https://doi.org/10.1186/s41072-023-00145-w>.
9. Campana EF, et al. CNR-Fincantieri joint projects: a successful example of collaboration between research and industry based on the open innovation approach. *J Open Innov Technol Market Complex*. 2020. <https://doi.org/10.3390/joitmc6010015>.
10. Roumboutsos A, Sys C, Vanelslander T. Imitation, co-opetition and open innovation in network industries: cases from ports. *Case Stud Transp Policy*. 2022;10(3):1627–39. <https://doi.org/10.1016/j.cstp.2022.06.002>.
11. Rupo D, Perano M, Centorri G, Vargas-Sanchez A. A framework based on sustainability, open innovation, and value cocreation paradigms—a case in an Italian maritime cluster. *Sustainability*. 2018;10(3):729. <https://doi.org/10.3390/su10030729>.
12. Witte P, Slack B, Keesman M, Jugie JH, Wiegman B. Facilitating start-ups in port-city innovation ecosystems: a case study of Montreal and Rotterdam. *J Transp Geogr*. 2018;71:224–34. <https://doi.org/10.1016/j.jtrangeo.2017.03.006>.
13. Garcia R, Wigger K, Hermann RR. Challenges of creating and capturing value in open eco-innovation: evidence from the maritime industry in Denmark. *J Clean Prod*. 2019;220:642–54. <https://doi.org/10.1016/j.jclepro.2019.02.027>.
14. Roukouni A, Lukosch H, Verbraeck A, Zuidwijk R. Let the game begin: enhancing sustainable collaboration among actors in innovation ecosystems in a playful way. *Sustainability (Switzerland)*. 2020;12(20):1–17. <https://doi.org/10.3390/su12208494>.
15. Monteiro PV. The role of knowledge-intensive service activities on inducing innovation in co-opetition strategies: lessons from the maritime cluster of the Algarve region. *Int J Manag Enterp Dev*. 2016;15(1):78–95. <https://doi.org/10.1504/IJMED.2016.075876>.
16. Ferasso M, Takahashi ARW, Gimenez FAP. Innovation ecosystems: a meta-synthesis. *Int J Innov Sci*. 2018;10(4):495–518. <https://doi.org/10.1108/IJIS-07-2017-0059>.
17. Granstrand O, Holgersson M. Innovation ecosystems: a conceptual review and a new definition. *Technovation*. 2020;90:102098. <https://doi.org/10.1016/j.technovation.2019.102098>.
18. Walker B, Holling CS, Carpenter SR, Kinzig AP. Resilience, adaptability and transformability in social-ecological systems. *Ecol Soc*. 2004. <https://doi.org/10.5751/ES-00650-090205>.
19. Folke C. Resilience: the emergence of a perspective for social–ecological systems analyses. *Glob Environ Change*. 2006;16(3):253–67. <https://doi.org/10.1016/j.gloenvcha.2006.04.002>.
20. Lam JSL, Notteboom T. The greening of ports: a comparison of port management tools used by leading ports in Asia and Europe. *Transp Rev*. 2014;34(2):169–89. <https://doi.org/10.1080/01441647.2014.891162>.
21. Meerow S, Newell JP, Stults M. Defining urban resilience: a review. *Landsc Urban Plan*. 2016;147:38–49. <https://doi.org/10.1016/j.landurbplan.2015.11.011>.

22. Ahern J. From fail-safe to safe-to-fail: sustainability and resilience in the new urban world. *Landsc Urban Plan.* 2011;100(4):341–3. <https://doi.org/10.1016/j.landurbplan.2011.02.021>.
23. Lengnick-Hall CA, Beck TE, Lengnick-Hall ML. Developing a capacity for organizational resilience through strategic human resource management. *Hum Resour Manag Rev.* 2011;21(3):243–55. <https://doi.org/10.1016/j.hrmr.2010.07.001>.
24. Duchek S. Organizational resilience: a capability-based conceptualization. *Bus Res.* 2020;13(1):215–46. <https://doi.org/10.1007/s40685-019-0085-7>.
25. Acciaro M, et al. Environmental sustainability in seaports: a framework for successful innovation. *Marit Policy Manag.* 2014;41(5):480–500. <https://doi.org/10.1080/03088839.2014.932926>.
26. Bhamra R, Dani S, Burnard K. Resilience: the concept, a literature review and future directions. *Int J Prod Res.* 2011;49(18):5375–93. <https://doi.org/10.1080/00207543.2011.563826>.
27. Jansen M, Brandellero A, van Houwelingen R. Port-city transition: Past and emerging socio-spatial imaginaries and uses in Rotterdam's makers district. *Urban Plan.* 2021;6(3):166–80. <https://doi.org/10.17645/up.v6i3.4253>.
28. Tsvetkova A, Hellström M. Creating value through autonomous shipping: an ecosystem perspective. *Marit Econ Logist.* 2022;24(2):255–77. <https://doi.org/10.1057/s41278-022-00216-y>.
29. Royer S, Gretzinger S, Brown K. The value adding web concept of clusters—strengthening and extending the fundament: resources. *Capab Rents' Manag Revue.* 2019;30(4):389–411. <https://doi.org/10.5771/0935-9915-2019-4-389>.
30. González-Cancelas N, Molina Serrano B, Soler-Flores F, Camarero-Orive A. Using the SWOT methodology to know the scope of the digitalization of the Spanish ports. *Logistics.* 2020. <https://doi.org/10.3390/logistics4030020>.
31. Ruuslahti H, Tikkanmäki I. End-users co-create shared information for a more complete real-time maritime picture. In: Liu K, Salgado AC, Bernardino J, Filipe J, Filipe J, editors. *IC3K 2017 - Proceedings of the 9th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management.* SciTePress; 2017. pp. 267–74. <https://doi.org/10.5220/0006559702670274>.
32. Wohlleber AJ, Bock M, Birkel H, Hartmann E. Implementing vital dynamic capabilities to succeed in digital transformation: a multiple-case study in maritime container shipping. *IEEE Trans Eng Manag.* 2024;71:13627–45. <https://doi.org/10.1109/TEM.2022.3201770>.
33. Vural CA, Göçer A, Halldórsson Á. Value co-creation in maritime logistics networks: a service triad perspective. *Transp Policy (Oxf).* 2019;84:27–39. <https://doi.org/10.1016/j.tranpol.2018.12.017>.
34. Gifford E, McKelvey M, Saemundsson R. The evolution of knowledge-intensive innovation ecosystems: co-evolving entrepreneurial activity and innovation policy in the West Swedish maritime system. *Ind Innov.* 2021;28(5):651–76. <https://doi.org/10.1080/13662716.2020.1856047>.
35. Burden H, Karlsson M, Haraldson S, Mellegård N, Olsson E. Accelerating acquisition in an open innovation ecosystem. In: 25th Americas Conference on Information Systems, AMCIS 2019, Association for Information Systems, 2019. [Online]. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85084021667%26partnerID=40%26md5=1867cec383d5af0d300e42266bbd0e50>
36. Snyder H. Literature review as a research methodology: An overview and guidelines. *J Bus Res.* 2019;104:333–9. <https://doi.org/10.1016/j.jbusres.2019.07.039>.
37. Stratton SJ. Literature reviews: methods and application. *Prehospital Disaster Med.* 2019;34(4):347–9. <https://doi.org/10.1017/S1049023X19004588>.
38. Linnenluecke MK, Marrone M, Singh AK. Conducting systematic literature reviews and bibliometric analyses. *Aust J Manag.* 2020;45(2):175–94. <https://doi.org/10.1177/0312896219877678>.
39. Gjøsæter AS, Kyvik Ø, Nesse JG, Årethun T. Business models as framework for sustainable value-creation: strategic and operative leadership challenges. *Int J Innov Sustain Dev.* 2021;15(1):50. <https://doi.org/10.1504/IJSD.2021.111549>.
40. Rivas-Hermann R, Köhler J, Scheepens AE. Innovation in product and services in the shipping retrofit industry: a case study of ballast water treatment systems. *J Clean Prod.* 2015;106:443–54. <https://doi.org/10.1016/j.jclepro.2014.06.062>.
41. Attanasio G, Battistella C, Chizzolini E. How do seaports use foresight to face environmental sustainability disruptions? *Transp Res Interdiscip Perspect.* 2024;25:101095. <https://doi.org/10.1016/j.trip.2024.101095>.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.