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OPEN INNOVATION AS A COORDINATION MECHANISM IN PORT ECOSYSTEMS: A COMPARATIVE ANALYSIS OF EUROPEAN SEAPORTS

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ABSTRACT
European seaports are undergoing transformative changes driven by digitalisation, sustainability demands, and increased interdependence in maritime logistics. As multi-actor systems within global supply networks, ports require innovative strategies to coordinate diverse stakeholders, knowledge flows, and institutional frameworks. This paper investigates how Open Innovation serves as a coordination mechanism in European port ecosystems and examines the influence of different governance configurations on sustainability-oriented value creation. Using a semi-structured literature review and qualitative comparative analysis, four case studies—Rotterdam, Valencia, Barcelona, and Motril-Granada—are examined alongside small and medium-sized Baltic ports. The findings reveal that Open Innovation varies based on port scale, ecosystem maturity, governance capacity, institutional mediation, digital readiness, and strategic focus. Rotterdam illustrates a distributed innovation ecosystem; Valencia represents an institutional model; Barcelona exemplifies smart-port and business-model innovation; Motril-Granada highlights a Blue Economy approach; and Baltic ports emphasise capacity building. While Open Innovation promotes stakeholder alignment and shared agenda-setting, challenges such as fragmented governance and varying resource capacities constrain its overall impact. This paper contributes to research on port innovation and maritime logistics by proposing a conceptual framework that views Open Innovation as a key coordination mechanism for sustainable port transformation.

Keywords: *Open Innovation, Port Ecosystem, Maritime Ports, Port Governance, business model innovation*

1. INTRODUCTION

European seaports are undergoing a profound transformation. Traditionally understood as sea–land interfaces and logistics nodes, ports have increasingly become complex ecosystems in which port authorities, terminal operators, shipping companies, logistics providers, technology firms, public agencies, research institutions, and local communities interact to generate economic, environmental, and social value. This transformation has been accelerated by digitalisation, sustainability pressures, changing supply chain requirements and the need to coordinate increasingly interdependent maritime logistics systems.

In this context, innovation has become a strategic condition for port competitiveness and sustainable development. However, innovation in ports is not merely a technological issue (Seisenbekov et al., 2026). Port-related innovation often involves regulatory, organisational, managerial, cultural and technological dimensions, requiring coordinated action among multiple actors. Vanelslander et al. (2019) show that port-related innovation is multidimensional, and that collaborative innovation or co-innovation is likely to become increasingly important for maritime and port-related innovation. Similarly, Acciaro and Sys (2020) argue that maritime innovation initiatives are often uncoordinated, unfocused and poorly managed, which may prevent them from delivering expected strategic outcomes. These insights suggest that the central challenge is not only how ports innovate, but how innovation is coordinated across fragmented ecosystems.

Open Innovation offers a relevant lens for addressing this challenge. Since Chesbrough's seminal contribution, Open Innovation has been understood as a model in which firms and organisations use purposive inflows and outflows of knowledge to accelerate innovation and expand the use of internal and external ideas (Chesbrough, 2003; Chesbrough & Bogers, 2014). In port ecosystems, however, Open Innovation cannot be reduced to the adoption of external ideas by individual organisations. Ports operate as multi-actor systems embedded in wider transport networks, urban regions and global supply chains. Therefore, Open Innovation in this context must be understood as an ecosystem-level process involving knowledge sharing, stakeholder alignment, institutional intermediation, digital integration and collaborative value creation.

This perspective is particularly relevant because ports display many characteristics of network industries. Their performance depends on interoperability, standards, information flows, hinterland connections and coordination among actors that may simultaneously cooperate and compete. Roumboutsos et al. (2022) show that innovation uptake in ports is closely related to network-industry characteristics, and that co-opetition, imitation and Open Innovation can support innovation diffusion, especially when standards and interoperability are required. This reinforces the need to analyse Open Innovation not only as a managerial practice, but as a coordination mechanism that enables ports to organise interdependencies across actors, technologies and institutional arrangements.

At the same time, sustainability has become a central driver of port transformation. Ports are increasingly expected to contribute to decarbonisation, circular economy, Blue Economy strategies, clean energy transitions, reduced environmental impacts and improved port–city relations. Sustainable value creation in ports requires a broader relational perspective that goes beyond conventional supply chain efficiency and incorporates multiple stakeholders, including civil society, policymakers, financial actors, employees, and local communities. De Martino (2021) argues that sustainable port development requires collaboration and stakeholder interaction across both the supply chain and the institutional environment. This means that Open Innovation in ports must be assessed not only in terms of operational efficiency, but also in relation to sustainability-oriented value creation.

Despite growing attention to smart ports, Port 4.0, digital platforms, environmental innovation and port innovation ecosystems, the literature remains fragmented. Existing studies provide valuable evidence on specific cases, technologies, or governance arrangements, but there remains limited understanding of how Open Innovation is operationalised across different types of European port ecosystems. In particular, less attention has been given to how different governance configurations — such as distributed innovation ecosystems, institutional intermediaries, smart-port strategies, territorial Blue Economy approaches and capacity-building initiatives in smaller ports — shape the coordination role of Open Innovation.

This paper addresses this gap by examining Open Innovation as a coordination mechanism in European port ecosystems. The guiding research question is: How is Open Innovation operationalised as a coordination mechanism across different European port ecosystem configurations?

The objective of the paper is to analyse how different port ecosystems organise Open Innovation and how these configurations support coordination, sustainability-oriented value creation and innovation performance. To achieve this objective, the study adopts a semi-structured literature review combined with a qualitative cross-case comparative synthesis. The analysis focuses on four port-specific cases — Rotterdam, Valencia, Barcelona and Motril-Granada — complemented by an aggregated comparative category of small and medium-sized Baltic ports. These cases are not treated as statistically representative units but as analytically distinct configurations that allow for comparison across different conditions of scale, governance capacity, institutional intermediation, digital readiness, and sustainability orientation.

The paper makes three contributions. First, it contributes to Open Innovation and port innovation literature by conceptualising Open Innovation as an ecosystem-level coordination mechanism rather than merely a set of collaborative practices or external knowledge flows. Second, it develops a comparative interpretation of different Open Innovation configurations in European port ecosystems, showing how scale, governance capacity, institutional support, digital infrastructure and strategic orientation shape innovation pathways. It proposes a conceptual framework that links enabling conditions, Open Innovation mechanisms, coordination functions, contextual constraints and sustainability-oriented value creation. In doing so, the paper provides a basis for future empirical research on how Open Innovation can support sustainable transformation in port systems.

The remainder of the paper is organised as follows. Section 2 develops a theoretical background, discussing Open Innovation, Sustainable Open Innovation, port innovation ecosystems, network coordination, sustainable value creation and governance. Section 3 presents the methodological approach. Section 4 provides comparative case synthesis and proposes a conceptual framework. Section 5 discusses the main findings, theoretical and practical implications, limitations and future research directions. Section 6 concludes the paper.

2. THEORETICAL BACKGROUND

2.1. OPEN INNOVATION AND SUSTAINABLE OPEN INNOVATION

Open Innovation has become one of the most influential perspectives in innovation management. Initially developed to explain how firms can purposively use internal and external knowledge flows to accelerate innovation, the concept challenged the closed innovation model by arguing that valuable knowledge is widely distributed and that organisations should combine internal capabilities with external ideas, technologies and market pathways (Chesbrough, 2003; Dahlander & Gann, 2010; West et al., 2006). In this sense, innovation is no longer conceived as an exclusively internal process, but as the outcome of interactions between organisations and their external environments.

The literature commonly distinguishes between inbound, outbound, and coupled Open Innovation. Inbound Open Innovation refers to the use of external ideas, knowledge and technologies within the organisation, whereas outbound Open Innovation concerns the external exploitation of internally developed knowledge. Coupled Open Innovation combines both directions through collaborative arrangements, partnerships, joint development projects and knowledge-sharing processes (Enkel et al., 2009, 2011; Lichtenthaler, 2011). More recent contributions have expanded Open Innovation beyond the firm level, emphasising inter-organisational networks, ecosystems and policy settings as relevant

levels of analysis (Bogers et al., 2018; West & Bogers, 2017). For port ecosystems, this coupled, ecosystem-level dimension is particularly relevant, since innovation often emerges from interactions among port authorities, terminal operators, logistics firms, technology providers, universities, research centres, start-ups and public institutions.

However, applying Open Innovation to complex, mature sectors require caution. Open Innovation should not be reduced to the presence of start-ups, incubators or informal collaboration. In mature industries, innovation may depend not only on weak ties that provide access to novel knowledge, but also on strong ties that enable trust, repeated interaction and the exchange of complex knowledge. Kazemargi et al. (2022) show that firms in mature industries can combine strong and weak supply ties to enhance both exploration and exploitation, thereby challenging the assumption that exploratory Open Innovation depends only on weak external relationships. This insight is particularly relevant for ports, where long-standing relationships, regulatory constraints and operational interdependencies shape the conditions under which openness can generate value.

More recently, the relationship between Open Innovation and sustainability has attracted growing attention. Sustainability challenges are systemic, multi-level and difficult to address through isolated organisational action. As a result, Open Innovation has increasingly been viewed as a potential mechanism for mobilising distributed knowledge and coordinating stakeholders around environmental and societal goals. Kimpimäki et al. (2022) argue that research on Sustainable Open Innovation remains fragmented, but that a multi-level understanding is needed to connect individual, organisational, city and regional levels of innovation. This is highly relevant to port ecosystems, which are simultaneously logistics infrastructures, business networks, urban interfaces, regional development assets and environmental pressure points.

Sustainable Open Innovation, therefore, extends the logic of openness by explicitly linking knowledge flows to sustainability-oriented outcomes (Adams et al., 2016). It implies that collaborative innovation should not only improve competitiveness or operational efficiency, but also contribute to environmental performance, social value and long-term resilience. Lippolis et al. (2023), for example, show that Open Innovation can act as a catalyst for sustainability when it is supported by open leadership, stakeholder engagement, organisational permeability and a strategic approach to corporate social responsibility. In port ecosystems, this means that Open Innovation must be assessed not only by the number of partnerships or technologies adopted, but also by its capacity to support sustainable transformation across the wider ecosystem.

This perspective is aligned with the broader literature on sustainability-oriented innovation and open eco-innovation, which emphasises that innovation should contribute not only to economic performance, but also to environmental and social value, while recognising the challenges of creating and capturing value in multi-actor sustainability-oriented networks (Adams et al., 2016; Garcia et al., 2019; Hermann & Wigger, 2017; Costa & Matias, 2020).

Building on these foundations, this paper conceptualises Open Innovation as an ecosystem-level coordination mechanism. Beyond a firm-centred perspective, Open Innovation is understood here as the process through which purposive knowledge flows, collaborative arrangements and boundary-spanning interactions are used to align heterogeneous actors, resources, standards, digital infrastructures and sustainability objectives across a port ecosystem (Adner, 2017; Bogers et al., 2018; West & Bogers, 2017; Ha et al., 2026). In port contexts, this coordination role is particularly critical because the adoption of innovation depends heavily on interoperability, co-opetition, standardisation, and multi-actor governance arrangements (Roumboutsos et al., 2022; Tijan et al., 2021; Vanelslander et al., 2019).

This definition also clarifies the boundary between related concepts. Open Innovation dif-

fers from general collaboration because it is specifically oriented towards innovation-related knowledge mobilisation and the purposeful use of knowledge flows (Chesbrough, 2003; Dahlander & Gann, 2010; Enkel et al., 2009). It differs from port governance in that it does not primarily concern formal authority structures, institutional mandates, or the allocation of decision rights, although it is shaped by them (de Langen et al., 2020; Zhang et al., 2019; Alsharaideh et al., 2026). Finally, it differs from value creation in that coordination is treated here as the alignment process itself, whereas value creation refers to the operational, environmental, social, and territorial outcomes generated by that alignment (De Martino, 2021; Tsvetkova & Hellström, 2022).

2.2. PORT INNOVATION ECOSYSTEMS AND NETWORK COORDINATION

Ports are no longer merely physical interfaces between sea and land. They have become complex innovation ecosystems embedded in global supply chains, regional economies and urban systems. A port ecosystem includes port authorities, terminal operators, shipping lines, logistics service providers, hinterland transport actors, customs authorities, technology firms, research institutions, regulators, municipalities and local communities. These actors are linked through flows of cargo, information, capital, knowledge and regulation. As such, port innovation is rarely the result of isolated action by a single organisation; it depends on the coordination of multiple actors with different interests, capabilities and incentives.

The literature on port innovation shows that innovation in this sector is multidimensional. Vanelslander et al. (2019) propose a typology of port-related innovation and show that innovation initiatives in the port sector often combine technological, organisational, managerial and cultural dimensions. Their analysis of 75 port-related innovation initiatives also indicates that collaborative innovation remains limited, but that co-innovation is likely to become increasingly important for the future of maritime and port-related innovation. This suggests that the key issue is not simply whether ports innovate, but how innovation is organised and coordinated across the port ecosystem.

Coordination is especially important because ports display characteristics of network industries. Their value depends on interoperability, compatibility, information exchange, hinterland connectivity, standards and the ability to synchronise operations across multiple actors. Roumboutsos et al. (2022) argue that ports, as nodes in wider transport networks, need to be analysed in relation to network-industry characteristics. Their study of Electronic Data Interchange and all-weather terminal cases shows that innovation uptake is shaped by co-opetition, imitation, Open Innovation and standardisation. This is particularly relevant for digital innovation, where isolated technological solutions may fail to generate systemic value if they are not interoperable or adopted by the wider port community.

From this perspective, Open Innovation in ports is not merely a voluntary managerial choice. It is structurally linked to the interdependent nature of port operations. Digital platforms, Port Community Systems, smart-port applications, blockchain, Internet of Things technologies and real-time data exchange require collective adoption, trust, data-sharing protocols and institutional arrangements. Without coordination, digitalisation may increase fragmentation rather than reduce it. Conversely, when supported by collaborative governance and shared standards, digital infrastructures can enhance information flows, reduce operational uncertainty and improve the synchronisation of maritime logistics chains.

The ecosystem perspective also helps to distinguish different configurations of port innovation. Mendes Constante et al. (2023), in their comparative analysis of Rotterdam and Valencia, show that port innovation ecosystems may differ substantially in their structure and governance. Rotterdam is characterised by a more distributed and connected ecosys-

tem, while Valencia presents a more centralised model in which Fundación Valenciaport plays a strong intermediary role. This distinction is important because it shows that Open Innovation does not have a single organisational form. It may be distributed across multiple actors, mediated by an institutional intermediary, driven by the port authority, organised through public–private partnerships, or embedded in territorial development strategies.

Business model innovation is another important dimension of port ecosystem transformation. Henríquez et al. (2022) analyse the Port of Barcelona and show how Industry 4.0 technologies can drive innovation in seaport business models through technology-push and market-pull mechanisms. Their study connects the smart-port and Port 4.0 concepts with data-driven services, stakeholder integration, strategic connectivity and new value creation. This reinforces the idea that digital innovation in ports should not be treated solely as technological adoption but as a reconfiguration of how ports create, deliver, and capture value. Recent evidence from maritime container shipping also highlights that digital transformation depends on dynamic capabilities rather than on technology deployment alone (Wohlleber et al., 2024).

At the same time, not all port ecosystems possess the same resources or maturity. Small and medium-sized ports often face limitations in digital readiness, human capital, financial resources, and absorptive capacity. Evidence from small and medium-sized Baltic ports shows that digital transformation in such contexts depends on capacity-building, organisational learning and cross-border cooperation. This makes it necessary to analyse Open Innovation in relation to port scale, ecosystem maturity and institutional capacity. Smaller ports may not replicate the innovation models of large hubs such as Rotterdam or Barcelona, but they may develop more adaptive and context-sensitive forms of collaborative innovation.

In summary, port innovation ecosystems require coordination mechanisms that align actors, technologies, and institutions. Open Innovation can perform this role by enabling knowledge sharing, collaborative experimentation, institutional intermediation, standardisation, and collective value creation. However, its effectiveness depends on the governance configuration of each port ecosystem and on the capacities available to transform openness into coordinated action.

2.3. SUSTAINABLE VALUE CREATION AND GOVERNANCE IN PORT ECOSYSTEMS

Sustainability has become a central dimension of contemporary port development. Ports are increasingly expected to reduce environmental externalities, contribute to decarbonisation, support circular economy strategies, improve port–city relations and participate in broader Blue Economy and energy-transition agendas. These expectations extend the role of ports beyond cargo handling and operational efficiency, requiring attention to the economic, environmental, social and territorial consequences of port activity.

The literature on sustainable value creation provides a useful basis for analysing this transformation. Conventional approaches to value creation tend to focus on cost, service quality, flexibility, delivery reliability, operational performance and customer satisfaction. By contrast, sustainability-oriented approaches expand the analysis to consider with whom and for whom value is created, how different stakeholders participate, and how economic, social, and ecological outcomes are distributed. De Martino (2021) conceptualises sustainable value creation in ports through a relational perspective, distinguishing between the supply chain level and the institutional environment level. This distinction is relevant because port sustainability depends not only on port operators and customers but also on policymakers, local communities, financial actors, civil society, and other institutional stakeholders.

Port governance is closely connected to this debate, as it shapes the institutional conditions under which sustainable value creation occurs. Governance concerns the allocation of authority, responsibilities, decision rights and coordination mechanisms among public and private actors. In a comprehensive review of 118 studies, Zhang et al. (2019) examine how and why ports are governed, identifying devolution and re-centralisation as major institutional tools and highlighting the importance of linking governance arrangements to strategic port objectives. This perspective is particularly useful for the present study as Open Innovation in ports depends on how institutional settings enable or constrain collaboration among heterogeneous actors.

Climate change has further expanded the scope of port governance. Ports are increasingly involved in mitigation and adaptation agendas, requiring coordination across wider supply chains. Monios et al. (2024) propose an updated conception of port governance under climate change, structured around four stakeholder groups: public policy, commercial actors, indirect actors and international shipping governance. Their analysis stresses that future port governance requires integrated mechanisms to share uncertain, unevenly distributed climate costs and benefits. For open innovation, this is critical because climate-oriented transformation demands collective investment, shared risk, cross-sector knowledge and long-term coordination.

Blue Economy strategies and ecosystem-level initiatives illustrate this territorial value-creation logic. The Motril-Granada case, for instance, demonstrates how port strategy can be structured around connectivity, clean energy, waste management and community relations, showing how sustainability-oriented innovation can be embedded in local development within smaller port contexts (Seisdedos & Carrasco, 2020). This confirms that innovation relies on actors that remain organisationally autonomous yet operationally interdependent—a finding consistent with maritime-cluster research on value co-creation and Open Innovation (Rupo et al., 2018).

Taken together, these contributions demonstrate that sustainable value creation in port ecosystems requires alignment across governance arrangements, stakeholder relationships, institutional conditions and ecosystem-level coordination. For this review, these elements provide the theoretical foundation for understanding Open Innovation not simply as inter-firm collaboration, but as a governance-shaped process oriented toward sustainable value creation. Accordingly, the comparative synthesis developed in this paper evaluates how different port ecosystems configure Open Innovation across institutional intermediation, stakeholder engagement, digital transformation, sustainability orientation and coordination capacity.

3.METHODOLOGICAL APPROACH

This study adopts a semi-structured literature review combined with a qualitative cross-case comparative synthesis. This methodological design is appropriate because the research question addresses a conceptually broad and interdisciplinary topic: the role of Open Innovation as a coordination mechanism in European port ecosystems. The topic lies at the intersection of innovation management, maritime logistics, port governance, digital transformation, sustainability transitions and regional development. As a result, the relevant evidence is dispersed across different research traditions, including conceptual studies, case studies, comparative analyses, review articles and sector-specific contributions.

Literature reviews are particularly useful for mapping, organising and critically interpreting fragmented bodies of knowledge, especially when a field is interdisciplinary or conceptually emerging (Snyder, 2019; Tranfield et al., 2003). Unlike narrowly systematic reviews, semi-structured and integrative reviews allow researchers to combine trans-

parency in search and selection procedures with interpretative flexibility in synthesising heterogeneous evidence (Grant & Booth, 2009; Torraco, 2005; Wong et al., 2013). This approach is therefore suitable for analysing Open Innovation in port ecosystems, where the evidence combines theoretical contributions, qualitative case studies, review articles and sector-specific analyses.

The literature on Open Innovation in port ecosystems is predominantly qualitative, conceptual, and case-based, combining diverse theoretical perspectives, case-study designs, and context-specific evidence. For this reason, statistical aggregation would not be appropriate. Instead, the study develops an interpretative synthesis of secondary evidence to identify how Open Innovation is configured across different port contexts and how it contributes to coordination, sustainability-oriented value creation, and ecosystem-level innovation. This approach is consistent with qualitative synthesis, which seeks to integrate findings from heterogeneous studies while preserving contextual meaning (Chenail, 2016; Snyder, 2019; Thomas & Harden, 2008).

The methodological design involved four stages: (1) literature identification and selection; (2) case selection; (3) development of analytical dimensions; and (4) qualitative cross-case synthesis. The process is summarised in Table 1.

Table 1. Research design

Element	Specification
Review type	Semi-structured literature review with qualitative cross-case comparative synthesis
Methodological rationale	Appropriate for interdisciplinary and heterogeneous bodies of literature combining conceptual, qualitative, review-based and case-study evidence
Main databases	Scopus and Web of Science
Supplementary search	Google Scholar and backward/forward reference checking
Search period	2014–2026
Final search date	20 March 2026
Language	English
Search fields	Title, abstract and keywords
Main document type	Peer-reviewed journal articles
Supplementary evidence	Academically grounded case-based studies and selected institutional sources when used in the reviewed literature
Search string	(“open innovation” OR “collaborative innovation” OR “innovation ecosystem” OR “co-creation”) AND (“sustainability” OR “sustainable development” OR “green port” OR “circular economy” OR “blue economy”) AND (“maritime port” OR “seaport” OR “port ecosystem” OR “port authority”)
Inclusion criteria	Studies addressing Open Innovation, collaborative innovation, innovation ecosystems, port governance, smart ports, digitalisation, Blue Economy, sustainability or value creation in maritime or port contexts
Exclusion criteria	Studies unrelated to maritime ports; purely technical studies without governance or innovation implications; inaccessible full texts; studies lacking sufficient relevance to the research question
Screening procedure	Title and abstract screening; full-text eligibility assessment; final selection according to conceptual, methodological and case-based relevance
Evidence organisation	Core theoretical literature; port innovation and governance literature; selected port-specific case studies; complementary evidence on small and medium-sized ports
Main cases	Rotterdam, Valencia, Barcelona and Motril-Granada
Aggregated comparative category	Small and medium-sized Baltic ports
Analytical dimensions	Open Innovation mechanisms; governance model; digital infrastructure; sustainability orientation; coordination mechanism; value creation; barriers and limitations
Synthesis method	Qualitative cross-case comparative synthesis
Type of generalisation	Analytical rather than statistical generalisation

Source: Authors’ elaboration

3.1. LITERATURE IDENTIFICATION AND SELECTION

The evidence base was constructed through a semi-structured selection of academic studies addressing Open Innovation, collaborative innovation, innovation ecosystems, port innovation, maritime logistics, port governance, digital transformation, smart ports, Blue Economy and sustainable value creation. The selection prioritised peer-reviewed journal articles and academically grounded case studies that provided conceptual, methodological or empirical relevance to the research question.

The literature search was conducted in Scopus and Web of Science. These databases were selected because they provide broad coverage of peer-reviewed research in innovation management, transport studies, maritime logistics, sustainability and governance. Google Scholar was used only as a supplementary tool to identify additional relevant works and to support backwards and forward reference checking. Such supplementary search strategies are commonly used in review studies to improve coverage when relevant evidence is dispersed across disciplines or when terminology varies across research traditions (Booth et al., 2016; Snyder, 2019).

The following Boolean string was applied to title, abstract, and keywords:

("open innovation" OR "collaborative innovation" OR "innovation ecosystem" OR "co-creation") AND ("sustainability" OR "sustainable development" OR "green port" OR "circular economy") AND ("maritime port" OR "seaport" OR "port ecosystem" OR "port authority")

The search covered the period from 2014 to 2026. This time window was selected because the last decade has seen intensified scholarly attention to digitalisation, sustainability transitions, smart ports, Blue Economy strategies and ecosystem-based innovation in maritime logistics. The final search was conducted on 20 March 2026.

The selection process followed three screening stages. First, titles and abstracts were screened to remove studies unrelated to ports, maritime logistics or innovation ecosystems. Second, full texts were assessed to determine whether each study contributed substantively to the research question. Third, the remaining studies were organised according to their conceptual and empirical relevance to comparative synthesis. This staged screening logic is consistent with review methodologies that require explicit selection and exclusion criteria to improve transparency and replicability (Booth et al., 2016; Tranfield et al., 2003).

Studies were included when they met at least one of the following criteria:

- they addressed Open Innovation, collaborative innovation, innovation ecosystems, co-creation or knowledge-sharing in port, maritime or logistics contexts;
- they examined port governance, smart ports, port digitalisation, Blue Economy, sustainability or value creation in ways relevant to innovation coordination;
- they provided case-based evidence on one of the selected port ecosystems or on comparable European port contexts;
- they contributed to the development of one or more analytical dimensions used in cross-case synthesis.

Studies were excluded when they were unrelated to maritime ports, focused exclusively on technical engineering performance without governance or innovation implications, lacked sufficient conceptual relevance to Open Innovation or port ecosystem coordination, or did not provide enough information to support analytical comparison.

The final evidence base was organised into four categories. The first category included core theoretical contributions on Open Innovation, Sustainable Open Innovation and innovation ecosystems. The second included studies on port innovation, port governance, smart ports and maritime innovation typologies. The third included case-based studies of Rotterdam, Valencia, Barcelona and Motril-Granada. The fourth included complemen-

tary evidence on small and medium-sized ports, with particular attention to Baltic ports, absorptive capacity, capacity-building and digital maturity.

The review process was semi-structured rather than fully systematic. This choice reflects the interdisciplinary and heterogeneous nature of the literature. The objective was not to exhaustively quantify all publications on Open Innovation and ports, but to identify and interpret the most relevant conceptual and case-based evidence for understanding Open Innovation as a coordination mechanism in port ecosystems. This positioning follows integrative review logic, in which the aim is to generate conceptual clarification and theoretical synthesis across diverse literature rather than to aggregate homogeneous empirical effects (Snyder, 2019; Torraco, 2005).

3.2. CASE SELECTION RATIONALE

The comparative synthesis focuses on four port-specific cases — Rotterdam, Valencia, Barcelona and Motril-Granada — complemented by an aggregated comparative category of small and medium-sized Baltic ports. The cases were selected through theoretical and purposive sampling rather than statistical sampling. The objective was to maximise analytical variation across different Open Innovation configurations and to compare how openness is organised under different conditions of scale, institutional maturity, digital infrastructure and sustainability orientation. Theoretical and purposive case selection is appropriate when cases are chosen for their capacity to illuminate theoretical constructs, reveal contrasts and support analytical generalisation (Eisenhardt, 1989; Flyvbjerg, 2006; Stake, 1995; Yin, 2018).

Rotterdam was selected because it represents a large European hub with a distributed and experimental innovation ecosystem. The literature associates Rotterdam with start-up facilitation, port-city innovation, serious games, digital logistics experimentation, collaborative learning and ecosystem orchestration. It is therefore useful for analysing Open Innovation in a mature, diversified and highly connected port ecosystem.

Valencia was selected because it exemplifies an institutionally mediated innovation ecosystem. In the literature, the role of Fundación Valenciaport is particularly relevant, as it operates as an intermediary organisation connecting the port authority, firms, universities, research actors and public institutions. Valencia therefore provides evidence of how Open Innovation can be structured through institutional intermediation, applied research and knowledge transfer.

Barcelona was selected because it represents a smart-port and business-model innovation pathway. Studies on the Port of Barcelona connect Industry 4.0 technologies, Port 4.0 strategies, strategic connectivity, smart-port capabilities and business model innovation. Barcelona is therefore relevant for analysing how digital technologies and long-term strategic planning shape Open Innovation and value creation in port ecosystems.

Motril-Granada was selected as a contrasting smaller-port case. Its relevance lies in how Open Innovation is connected to the Blue Economy, territorial development, sustainability, port-community engagement, and local research collaboration. Motril-Granada provides an analytically useful contrast with larger, more institutionally mature innovation ecosystems.

Small and medium-sized Baltic ports were included as an aggregated comparative category rather than as individual port-specific cases. This category provides complementary evidence on resource-constrained port ecosystems, especially regarding digital maturity, absorptive capacity, human capital, organisational learning and cross-border capacity-building. Its inclusion helps avoid treating Motril-Granada as the only representation of smaller-port contexts and strengthens the analysis of capacity-building constraints in small and medium-sized port ecosystems.

The selected cases are not symmetrical empirical units with identical evidential depth. Rotterdam, Valencia and Barcelona are more extensively documented in the literature, whereas Motril-Granada and the Baltic ports provide more specific or aggregated evidence. This asymmetry is acknowledged as a methodological limitation. However, it is also analytically useful because the study does not aim to rank ports or compare equivalent performance indicators. Instead, it compares different configurations through which Open Innovation is discussed and operationalised in European port ecosystems. This approach is consistent with comparative case synthesis, in which analytical value derives from theoretically meaningful contrasts rather than statistical representativeness (Eisenhardt & Graebner, 2007; Yin, 2018).

The case selection logic is summarised in Table 2. The cases were selected to represent analytically distinct Open Innovation configurations rather than to be statistically representative of port categories.

Table 2. Case selection rationale

Case / comparative category	Type of evidence	Open Innovation configuration	Analytical relevance
Rotterdam	Port-specific case	Distributed and experimental innovation ecosystem	Represents a large and mature European hub where Open Innovation is associated with start-up facilitation, port-city innovation, collaborative experimentation and digital logistics
Valencia	Port-specific case	Institutional-intermediated innovation ecosystem	Illustrates how an intermediary organisation can support knowledge transfer, applied research, stakeholder engagement and innovation orchestration
Barcelona	Port-specific case	Smart-port and business-model innovation ecosystem	Shows how digital technologies, strategic connectivity and Port 4.0-oriented initiatives can shape innovation pathways and value creation
Motril-Granada	Port-specific case	Blue Economy and territorial innovation ecosystem	Provides a contrasting smaller-port case where Open Innovation is linked to sustainability, territorial development, local research collaboration and port-community engagement
Small and medium-sized Baltic ports	Aggregated comparative category	Capacity-building and resource-constrained innovation ecosystems	Provides complementary evidence on digital maturity, absorptive capacity, human capital, organisational learning and resource constraints in smaller port ecosystems

Source: Authors' elaboration

3.3. ANALYTICAL STRATEGY AND COMPARATIVE DIMENSIONS

The selected studies were analysed through qualitative cross-case comparative synthesis. Cross-case analysis is useful when the objective is to identify patterns, similarities and differences across cases while retaining sensitivity to contextual specificities (Miles et al., 2014; Yin, 2018). In case-based research, comparison can support theory development by

allowing constructs to be examined across contrasting empirical settings (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). In this study, the method was used to compare how Open Innovation is operationalised across different European port ecosystem configurations and to examine its relationship to coordination and sustainability-oriented value creation.

The analytical procedure followed an abductive logic. The theoretical background informed the initial analytical dimensions, while the case-based literature refined them in the context of port ecosystems. Abductive reasoning is appropriate when research seeks to refine conceptual understanding by moving iteratively between theory and empirical material, rather than testing predefined hypotheses or developing theory from a blank slate (Dubois & Gadde, 2002; Timmermans & Tavory, 2012).

To address the study's conceptual focus, the analysis was structured around seven dimensions: Open Innovation mechanisms, governance model, digital infrastructure, sustainability orientation, coordination mechanism, value creation, and barriers and limitations.

The first dimension, Open Innovation mechanisms, refers to the specific practices through which knowledge, ideas, technologies and resources circulate across organisational boundaries. These may include start-up programmes, research partnerships, institutional intermediaries, collaborative projects, open data initiatives, digital platforms, public–private partnerships and Blue Economy projects.

The second dimension, governance model, captures the institutional arrangements through which innovation is organised. This includes distributed governance, intermediary-led models, port-authority-led strategies, smart-port governance and territorial/community-oriented governance.

The third dimension, digital infrastructure, refers to the technologies and data systems that support innovation and coordination. These include Port Community Systems, smart-port platforms, Internet of Things technologies, blockchain, data-sharing systems, digital twins and real-time information exchange.

The fourth dimension, sustainability orientation, captures how innovation is linked to environmental, social and territorial objectives. This includes decarbonisation, clean energy, circular economy, Blue Economy, green-port strategies, port-city integration and local development.

The fifth dimension, coordination mechanism, refers to the processes through which Open Innovation helps align actors, resources, technologies and objectives. These mechanisms include standardisation, co-opetition, institutional intermediation, stakeholder alignment, collaborative learning, knowledge transfer, interoperability, and shared agenda-setting.

The sixth dimension, value creation, captures the types of outcomes associated with Open Innovation. These may include operational efficiency, innovation performance, knowledge creation, stakeholder value, environmental improvement, territorial development and ecosystem resilience.

The seventh dimension, barriers and limitations, captures factors that constrain the effectiveness of Open Innovation. These include fragmented governance, limited standardisation, institutional inertia, weak absorptive capacity, resource constraints, uneven digital maturity, limited evaluation frameworks and stakeholder misalignment.

These dimensions served as interpretative lenses for organising comparative synthesis and differentiating evidence from the reviewed literature and the authors' analytical interpretation. This distinction is important because the study relies on secondary sources and does not claim to produce primary empirical findings. In qualitative synthesis, such interpretative categories help organise heterogeneous evidence while preserving contextual meaning and avoiding unsupported statistical inference (Snyder, 2019; Thomas &

Harden, 2008; Torraco, 2005).

The analytical dimensions used for the cross-case synthesis are presented in Table 3. These dimensions were used as interpretative lenses rather than as rigid quantitative coding categories.

Table 3. Analytical dimensions for the cross-case synthesis

Analytical dimension	Definition	Focus of comparison	Key supporting literature
Open Innovation mechanisms	Practices through which knowledge, ideas, technologies and resources circulate across organisational boundaries	Start-up programmes; research partnerships; institutional intermediaries; open data; digital platforms; public–private projects	Chesbrough (2003); Chesbrough & Bogers (2014); Enkel et al. (2009); Dahlander & Gann (2010)
Governance model	Institutional arrangements through which innovation is organised and coordinated	Distributed governance; intermediary-led governance; port-authority-led strategy; territorial or community-oriented governance	de Langen et al. (2020); Zhang et al. (2019); Tijan et al. (2021); Vanelslander et al. (2019)
Digital infrastructure	Technologies and data systems that support innovation, coordination and information exchange	Port Community Systems; smart-port platforms; IoT; blockchain; digital twins; real-time information exchange	Carlan et al. (2016); Costa & Matias (2020); Tijan et al. (2021); Cavalli et al. (2021); Roumboutsos et al. (2022)
Sustainability orientation	The extent to which innovation is connected to environmental, social and territorial objectives	Decarbonisation; clean energy; circular economy; Blue Economy; green-port strategies; port-city integration	Adams et al. (2016); Garcia et al. (2019); Costa & Matias (2020); De Martino (2021); Monios et al. (2024)
Coordination mechanism	Processes through which actors, resources, standards, technologies and objectives are aligned	Standardisation; interoperability; co-opetition; stakeholder alignment; collaborative learning; shared agenda setting	Adner (2017); Roumboutsos et al. (2022); Roukouni et al. (2020); Vanelslander et al. (2019)
Value creation	Outcomes generated or expected from Open Innovation processes	Operational efficiency; knowledge creation; environmental improvement; stakeholder value; territorial development; ecosystem resilience	De Martino (2021); Tsvetkova & Hellström (2022); Rupo et al. (2018); Jansen & Hein (2023)
Barriers and limitations	Factors that constrain the effectiveness or scalability of Open Innovation	Governance fragmentation; limited resources; weak absorptive capacity; institutional inertia; uneven digital maturity; lack of evaluation frameworks	Kazemargi et al. (2022); Meyer et al. (2021, 2023, 2024); Wohlleber et al. (2024); Acciaro & Sys (2020)

Source: Authors' elaboration

3.4. METHODOLOGICAL SCOPE AND LIMITATIONS

The methodological approach has several limitations. First, the study relies on secondary evidence rather than primary empirical data. It does not include interviews, direct observation or original fieldwork. As a result, the analysis depends on the availability, depth and methodological quality of existing studies. This limitation is explicitly acknowledged and addressed by positioning the paper as a review-based comparative synthesis rather than an empirical case study.

Second, the selected cases differ in scale, institutional maturity, geographical context and evidential depth. Rotterdam, Valencia and Barcelona are more extensively documented in the literature, whereas Motril-Granada and the Baltic ports provide more specific or aggregated evidence. This limits direct comparability, but it is consistent with the study's objective of identifying different configurations of Open Innovation rather than comparing equivalent empirical units.

Third, the aggregated category of small and medium-sized Baltic ports is not directly equivalent to the four port-specific cases. It is included as complementary evidence to strengthen the analysis of resource-constrained and capacity-building-oriented port ecosystems. The category should therefore be interpreted as a comparative analytical category, not as a single case equivalent to Rotterdam, Valencia, Barcelona or Motril-Granada.

Fourth, the study does not measure the direct performance effects of Open Innovation. Claims regarding coordination, value creation, and sustainability are drawn from the reviewed literature and the comparative synthesis. Therefore, the findings should be understood as analytical generalisations rather than statistical generalisations. This form of generalisation is appropriate in case-based and review-based research when findings are used to refine concepts, identify mechanisms or generate propositions for future research rather than infer population-level regularities (Yin, 2018).

Finally, the conceptual framework emerging from the study should be treated as a basis for future empirical testing. It identifies how Open Innovation may function as a coordination mechanism across different port ecosystem configurations, but further research using interviews, surveys, longitudinal case studies, or mixed methods would be required to empirically validate and refine the framework.

4. OVERVIEW OF THE COMPARATIVE CASES

The comparative synthesis examines four port-specific cases — Rotterdam, Valencia, Barcelona and Motril-Granada — together with an aggregated comparative category of small and medium-sized Baltic ports. These cases represent different configurations of Open Innovation in European port ecosystems, rather than a statistically representative sample of European ports. The purpose of the comparison is to identify how Open Innovation mechanisms are organised across different port contexts and how they relate to governance arrangements, digital infrastructures, sustainability orientation and coordination capacity.

The evidence base suggests that Open Innovation in port ecosystems is strongly shaped by contextual conditions. Large hub ports, such as Rotterdam and Barcelona, tend to have more diversified innovation ecosystems, greater access to technological infrastructures and stronger connections with start-ups, research actors and global logistics networks. Valencia offers a distinctive configuration in which institutional intermediation plays a central role. Motril-Granada provides a smaller-port case in which innovation is linked to Blue Economy, territorial development and sustainability-oriented port-community engagement. The Baltic small and medium-sized ports provide complementary evidence on capacity-building challenges, digital maturity and resource constraints in smaller port ecosystems.

The cases are therefore treated as analytically distinct configurations. Rotterdam is examined as a distributed and experimental innovation ecosystem; Valencia as an institutional-intermediated model; Barcelona as a smart-port and business-model innovation pathway; Motril-Granada as a Blue Economy and territorial innovation configuration; and the Baltic small and medium-sized ports as a capacity-building and resource-constrained category.

4.1. OPEN INNOVATION CONFIGURATIONS ACROSS PORT ECOSYSTEMS

Rotterdam is frequently presented in the literature as one of the most mature European examples of a port innovation ecosystem. The port's innovation configuration is associated with a distributed set of actors, including the Port of Rotterdam, the municipality, research organisations, start-up accelerators, knowledge platforms and private companies. Mendes Constante et al. (2023) describe Rotterdam's innovation ecosystem as "distributed and connected", contrasting it with Valencia's more centralised configuration.

A central feature of Rotterdam is the combination of experimentation, research cooperation and entrepreneurship. The literature identifies several ecosystem components in Rotterdam, including training infrastructure, talent recruitment, research facilities, test environments, support for start-ups and scale-ups, venture capital, innovation-oriented regulations and meeting spaces for entrepreneurs. Mendes Constante et al. (2023) also note the role of initiatives such as the Port Innovation Barometer, World Port Hackathon and SmartPort Summit in fostering an innovation-oriented culture. Start-up facilitation and port-city innovation ecosystems have also been discussed as mechanisms for connecting entrepreneurial activity with port development, as illustrated by comparative work on Montreal and Rotterdam (Witte et al., 2018).

Rotterdam also provides evidence of collaborative learning mechanisms. Studies on serious games and sustainable logistics innovation show how experimental tools can be used to reveal stakeholder tensions, support learning and explore adoption barriers in complex logistics systems (Roukouni et al., 2020). In this respect, Rotterdam illustrates a form of Open Innovation in which experimentation and ecosystem interactions are used to address uncertainty and interdependence.

From a coordination perspective, Rotterdam's configuration suggests that Open Innovation may operate through multiple distributed channels rather than through a single institutional intermediary. The strength of this model lies in the density of its ecosystem and in the availability of specialised actors, platforms and experimentation spaces. At the same time, distributed ecosystems may also require strong alignment mechanisms to prevent fragmentation and to ensure that innovation initiatives address shared port-system challenges rather than isolated organisational interests

4.2. VALENCIA: INSTITUTIONAL-INTERMEDIATED INNOVATION ECOSYSTEM

Valencia represents a contrasting configuration. While Rotterdam is characterised as distributed and connected, Valencia's port innovation ecosystem is more centralised and strongly mediated by Fundación Valenciaport. Mendes Constante et al. (2023) describe Fundación Valenciaport as a private, non-profit entity created in 2004 by the Port Authority of Valencia together with port cluster companies, associations, universities, the city, the region and other institutions in the port community. Its creation is presented as a deliberate effort to promote an innovation culture in Valencia's port cluster.

The role of Fundación Valenciaport is central to Valencia's Open Innovation configuration. It supports applied research, innovation projects, training, internationalisation and cooperation within the port-logistics community. The evidence indicates that developing the innovation ecosystem is a key action in the port cluster's innovation plan, highlighting

the importance of institutions in leading port clusters, aligning the port community, and establishing a common agenda on human capital, research, and innovation.

This model is analytically relevant because it illustrates how Open Innovation can be organised through institutional intermediation. In Valencia, the intermediary institution serves as a bridge among the port authority, firms, research organisations, universities, and other ecosystem actors. This reduces coordination complexity by providing a focal structure for knowledge transfer, project development and collaborative learning.

However, the literature also points to possible limitations. Mendes Constante et al. (2023) identify cultural constraints, including a limited culture of innovation, a short-term orientation, and a need for stronger collaboration. These limitations suggest that institutional intermediation can support Open Innovation but does not automatically eliminate barriers related to organisational culture, long-term commitment or stakeholder alignment.

4.3. BARCELONA: SMART-PORT AND BUSINESS-MODEL INNOVATION PATHWAY

Barcelona represents a configuration in which Open Innovation is closely associated with smart-port development, digital technologies and business model innovation. Examining the Port of Barcelona, Henríquez et al. (2022) analyse how Industry 4.0 technologies drive business model innovation, linking the evolution of seaports—from simple sea–land interfaces to value-adding entities in global supply chains—with concepts such as fifth-generation ports, smart ports and Port 4.0.

The Barcelona case is particularly useful for analysing the relationship between technology adoption and value creation. Henríquez et al. (2022) argue that Industry 4.0 technologies affect seaport business models through technology-push and market-pull mechanisms, reshaping how value is created, distributed and captured. In this sense, Barcelona's strategy cannot be reduced to technological adoption alone; it represents a comprehensive reconfiguration of the port's role, services, stakeholder relationships and value proposition. This perspective aligns with studies on the Port of Barcelona's Vision 2040, which conceptualise the port of the future through long-term strategic transformation and business model innovation (Garrido Salsas et al., 2022).

Furthermore, Barcelona provides key insights for the smart-port dimension of the comparative synthesis. In this context, smartness extends beyond automation to encompass enhanced Port Community Systems, real-time data interchange, digitally enabled synchronisation, port-city integration and sustainability goals (Henríquez et al., 2022).

From an Open Innovation perspective, Barcelona illustrates how digital infrastructures and smart-port strategies can create conditions for stronger stakeholder integration. However, this pathway also depends on the port's ability to align technology adoption with governance, market needs and business model transformation. The case therefore helps clarify that digital transformation becomes relevant to Open Innovation only when it enables new forms of coordination, value creation, and ecosystem interaction.

4.4. MOTRIL-GRANADA: BLUE ECONOMY AND TERRITORIAL INNOVATION CONFIGURATION

Motril-Granada provides a smaller-port case in which innovation is connected to Blue Economy, sustainability and territorial development. Seisdedos & Carrasco (2020) describe the Port of Motril-Granada's Blue Economy strategy as structured around four areas: connections, innovation, sustainability, and Motril itself and its surroundings. The article also states that the port encourages Open Innovation by integrating the private sector with research institutions, technological centres and universities.

The case differs from Rotterdam, Valencia and Barcelona because it is not primarily presented as a large-scale smart-port ecosystem or as a highly institutionalised innovation system. Its relevance lies in the way innovation is embedded in the port's local and territorial development agenda. The evidence indicates that the port seeks to strengthen traditional, emerging, and innovative sectors connected to the Blue Economy, while aligning its activities with European Blue Economy policies.

Motril-Granada also demonstrates sustainability-oriented initiatives. The article identifies activities related to marine and coastal ecosystems, renewable energy, climate change mitigation, energy efficiency and zero-waste processes. It also refers to specific initiatives such as shore connection, biodiversity protection, port reception facilities for waste and cargo residues, and the positioning of the port as a "Blue Port".

In analytical terms, Motril-Granada is best understood as a contrasting case rather than as a direct equivalent to larger ports. It allows the comparison to include a smaller-port configuration in which Open Innovation is linked to local development, port-community involvement, and sustainability-oriented positioning. The case should therefore be interpreted with caution: it illustrates a territorial and Blue Economy-oriented innovation pathway, but it does not provide the same level of evidence on digital maturity, ecosystem density, or institutionalised innovation governance as Rotterdam, Valencia, or Barcelona.

4.5. SMALL AND MEDIUM-SIZED BALTIC PORTS: CAPACITY-BUILDING AND RESOURCE-CONSTRAINED INNOVATION ECOSYSTEMS

The small and medium-sized Baltic ports are included as an aggregated comparative category. This category does not represent a single port-specific case but provides complementary evidence on the conditions under which smaller and medium-sized ports engage with digital transformation and innovation.

Meyer et al. (2021) show that small and medium-sized ports in the Baltic Sea Region are important regional nodes and gateways of economic and social interaction but are also exposed to specific vulnerabilities. They are often located outside major economic centres, only partly included in the TEN-T network, and characterised by lower freight volumes, limited specialisation, outdated infrastructure, a lack of investment, and a demand for new business models.

The evidence also indicates a tension between agility and capacity constraints. Small and medium-sized ports may be more flexible in adapting to new market challenges, but they are constrained by limited human capital and key employee skills. Meyer et al. (2021) therefore propose a cross-border capacity-building framework to support digital transformation in small and medium-sized port ecosystems, drawing on concepts such as absorptive capacity, organisational learning, transformation, resource-based view, dynamic capabilities, Open Innovation and service design.

This aggregated category strengthens the comparative synthesis in two ways. First, it prevents the analysis of smaller ports from relying only on Motril-Granada. Second, it highlights that Open Innovation in smaller and medium-sized ports may depend less on mature innovation infrastructures and more on capacity-building, training, knowledge transfer, and cross-border cooperation. In this sense, the Baltic ports category contributes to understanding how resource-constrained ecosystems may develop innovation capabilities through shared learning and regional collaboration.

4.6. CROSS-CASE SYNTHESIS

The cross-case synthesis indicates that Open Innovation is not operationalised through a single model across European port ecosystems. Instead, the reviewed cases reveal five an-

alytically distinct configurations: distributed experimentation in Rotterdam, institutional intermediation in Valencia, smart-port and business-model innovation in Barcelona, Blue Economy and territorial innovation in Motril-Granada, and capacity-building in small and medium-sized Baltic ports. These configurations were derived from the case-based evidence discussed in Sections 4.1–4.5, including studies on Rotterdam's experimental and ecosystem-oriented innovation practices, Valencia's intermediary-led innovation model, Barcelona's smart-port and business-model innovation pathway, Motril-Granada's Blue Economy strategy, and capacity-building dynamics in small and medium-sized Baltic ports (González-Cancelas et al., 2020; Meyer et al., 2023, 2024; Seisdedos & Carrasco, 2020; Suárez-Gargallo & Zaragoza-Sáez, 2023; Vanelslander et al., 2019).

The comparison should therefore be interpreted as an analytical synthesis of different Open Innovation configurations, rather than as a ranking of port performance. The cases are not symmetrical empirical units with identical evidential depth. Rotterdam, Valencia and Barcelona are more extensively documented in the literature, whereas Motril-Granada and the Baltic ports provide more focused or aggregated evidence. However, this asymmetry is analytically useful because it allows the synthesis to compare how Open Innovation operates under different ecosystem conditions.

A first cross-case pattern concerns the relationship between port scale and innovation configuration. Rotterdam illustrates how large, mature hub ports may support Open Innovation through distributed experimentation, start-up engagement, research platforms, hackathons, serious games, and multiple innovation spaces (Mendes Constante et al., 2023; Roukouni et al., 2020). Valencia shows a different model, in which the innovation ecosystem is more strongly mediated by Fundación Valenciaport, which acts as an institutional intermediary connecting firms, port authorities, universities, research actors and public institutions (Mendes Constante et al., 2023). Barcelona, in turn, illustrates a smart-port pathway in which digital technologies and Port 4.0 strategies are linked to business model innovation. By contrast, Motril-Granada and the Baltic ports suggest that smaller and medium-sized ports may rely less on dense innovation infrastructures and more on territorial collaboration, Blue Economy positioning, skills development and capacity-building. This comparison suggests that the configuration of Open Innovation is shaped by the resources, institutional structures and strategic priorities available within each port ecosystem (Vanelslander et al., 2019; Suárez-Gargallo & Zaragoza-Sáez, 2023; Seisdedos & Carrasco, 2020; Meyer et al., 2023, 2024).

A second pattern concerns the distinction between governance model and coordination mechanism. Governance refers to the institutional arrangements through which innovation is organised, while coordination refers to the process through which actors, resources, standards, technologies and objectives are aligned. Rotterdam's distributed governance requires coordination through ecosystem interaction, experimentation and collaborative learning. Valencia's intermediary-led governance supports coordination through knowledge transfer, project development and institutional intermediation. Barcelona's smart-port governance depends on coordination between technological adoption, business model transformation and stakeholder integration. Motril-Granada's territorial governance requires coordination between port development, local actors, research institutions and Blue Economy objectives. In the Baltic ports, coordination is mainly expressed through cross-border learning, absorptive capacity, and human capital development. Thus, the comparison clarifies that governance provides the institutional setting, whereas coordination concerns the alignment mechanisms through which Open Innovation becomes operational. This distinction is consistent with the ecosystem view of innovation, which emphasises actor interdependence and alignment, and with port

governance literature, which highlights the role of institutional arrangements, decision rights and public–private coordination in port development (Adner, 2017; de Langen et al., 2020; Zhang et al., 2019).

A third cross-case pattern concerns the role of digital infrastructure. In Rotterdam and Barcelona, digitalisation appears as a more central element of the innovation configuration. Rotterdam connects digital logistics, experimentation and ecosystem interaction, while Barcelona links Industry 4.0 technologies, Port Community Systems, strategic connectivity and business model innovation. In Valencia, digitalisation is relevant but is mediated through institutional support, applied research and innovation projects. In Motril-Granada, the dominant logic is not primarily about digital transformation but about the Blue Economy and territorial sustainability. In the Baltic ports, digitalisation appears mainly as a capacity-building challenge, constrained by limited resources, skills gaps and uneven digital maturity. This comparison suggests that digital infrastructure does not automatically produce Open Innovation. Its coordination value depends on whether digital tools are embedded in governance arrangements, stakeholder relationships and shared innovation objectives (Tijan et al., 2021; Roumboutsos et al., 2022; Vanelslander et al., 2019).

A fourth pattern concerns sustainability-oriented value creation. Across cases, sustainability is not a single or uniform outcome. In Rotterdam, sustainability is associated with the energy transition, experimentation in sustainable logistics, and an innovation culture. In Valencia, it is connected to human capital, knowledge transfer and port-logistics innovation. In Barcelona, it is linked to smart-port integration, strategic connectivity and the reconfiguration of value creation through digital technologies. In Motril-Granada, sustainability is expressed through Blue Economy, territorial development, port-community engagement and environmental positioning. In the Baltic ports, sustainability is connected to regional resilience, digital readiness, organisational learning and competitiveness in resource-constrained contexts. The synthesis therefore suggests that sustainable value creation in port ecosystems is multidimensional, including operational, environmental, social, territorial and ecosystem-level outcomes (De Martino, 2021; Monios et al., 2024; Tsvetkova & Hellström, 2022).

A fifth pattern concerns the conditions under which Open Innovation supports coordination. The cases indicate that openness alone is insufficient. Open Innovation becomes a coordination mechanism only when knowledge flows, partnerships, digital infrastructures and collaborative projects are connected to shared objectives and institutionalised interaction. In Rotterdam, the challenge is to align multiple distributed initiatives. In Valencia, the challenge is to expand innovation culture and avoid over-reliance on a central intermediary. In Barcelona, the challenge is to ensure that technology adoption is connected to business model transformation and stakeholder integration. In Motril-Granada, the challenge is to translate Blue Economy positioning into a sustained capacity for innovation. In the Baltic ports, the challenge is to overcome limited human capital, resource constraints and uneven digital maturity. These differences show that Open Innovation may enable coordination, but only under specific governance and capacity conditions (Meyer et al., 2023, 2024).

Finally, the synthesis reveals recurrent barriers across the cases. These include fragmented governance, limited innovation culture, weak standardisation, uneven absorptive capacity, resource constraints, limited human capital and difficulties in scaling innovation beyond individual projects. These barriers are important because they prevent Open Innovation from being treated as an inherently positive or self-executing process. Rather, the evidence suggests that Open Innovation requires deliberate coordination structures, institutional capacity, stakeholder alignment and evaluation mechanisms capable of

translating openness into collective action and sustainable value creation (Chesbrough, 2003; Adner, 2017; de Langen et al., 2020; Tijan et al., 2021).

Comparative synthesis is summarised in Table 4.

Table 4. Comparative synthesis of Open Innovation configurations in European port ecosystems

Case/category	OI configuration	Governance model	Main OI mechanisms	Coordination mechanism	Sustainability-oriented value creation	Main limitations
Rotterdam	Distributed and experimental innovation ecosystem	Distributed ecosystem governance	Start-ups, research platforms, hackathons, serious games, experimentation spaces	Ecosystem interaction, collaborative learning and experimentation	Energy transition, digital logistics, sustainable logistics experimentation and innovation culture	Risk of fragmentation; need to align multiple initiatives and actors
Valencia	Institutional-intermediated innovation ecosystem	Intermediary-led governance	Fundación Valenciaport, applied research, training, innovation projects and OpenTop	Institutional intermediation, knowledge transfer and port-community alignment	Human capital development, logistics innovation and sustainable port-logistics development	Limited innovation culture; short-term orientation; need for broader collaboration
Barcelona	Smart-port and business-model innovation pathway	Smart-port and strategy-led governance	Industry 4.0 technologies, Port 4.0 strategy, PCS, digital platforms and business model innovation	Digital and strategic connectivity, stakeholder integration and technology-enabled coordination	Smart-port integration, strategic connectivity, new value creation and business model transformation	Risk of technology-driven innovation without sufficient governance and stakeholder alignment
Motril-Granada	Blue Economy and territorial innovation configuration	Territorial and sustainability-oriented governance	Blue Economy projects, research collaboration, port-community engagement and sustainability initiatives	Territorial alignment, local collaboration and port-community integration	Blue Economy development, environmental positioning, territorial value and port-city sustainability	More limited evidence on digital maturity, ecosystem density and institutionalised innovation governance
Small and medium-sized Baltic ports	Capacity-building and resource-constrained innovation ecosystems	Regional and cross-border capacity-building governance	Training, knowledge transfer, organisational learning, absorptive capacity and cross-border cooperation	Cross-border learning, skills development and capacity-building	Digital readiness, regional resilience, competitiveness and organisational learning	Resource constraints; limited human capital; uneven digital maturity; infrastructure limitations

Source: Authors' elaboration based on the case-based literature reviewed in Sections 4.1–4.5

4.7. CONCEPTUAL FRAMEWORK: OPEN INNOVATION AS AN ECOSYSTEM-LEVEL COORDINATION MECHANISM

Based on the cross-case synthesis, this study proposes a conceptual framework to understand Open Innovation as an ecosystem-level coordination mechanism within port ecosystems. The framework does not claim to establish causal relationships or measure performance effects. Rather, it synthesises the reviewed literature into an analytical structure that explains how Open Innovation may support coordination among heterogeneous actors, infrastructures, and sustainability objectives.

The framework builds on the understanding of Open Innovation as purposive knowledge flows across organisational boundaries (Chesbrough, 2003; Chesbrough & Bogers, 2014), while extending this logic to ecosystem-level settings in which innovation depends on the alignment of interdependent actors, complementary resources and shared value propositions (Adner, 2017; Bogers et al., 2018; West & Bogers, 2017). In port ecosystems, this coordination role is particularly relevant because innovation adoption depends not only on technological availability, but also on interoperability, co-opetition, governance arrangements, stakeholder alignment and institutional capacity (de Langen et al., 2020; Roumboutsos et al., 2022; Tijan et al., 2021; Vanelslander et al., 2019).

The framework is organised around four interrelated components: enabling conditions, Open Innovation mechanisms, coordination functions, and sustainability-oriented val-

ue creation. These components are moderated by contextual constraints, including port scale, ecosystem maturity, governance fragmentation, absorptive capacity, resource availability, digital readiness and evaluation capacity.

First, enabling conditions refer to the institutional, organisational and technological factors that make Open Innovation possible in port ecosystems. The cross-case synthesis suggests that Open Innovation is more likely to become operational when port ecosystems possess governance capacity, institutional intermediation, digital infrastructure, stakeholder trust, absorptive capacity and a clear sustainability orientation. These conditions are not evenly distributed across port ecosystems. Large ports such as Rotterdam and Barcelona tend to have more developed innovation infrastructures, whereas smaller and medium-sized ports may depend more strongly on capacity-building, territorial collaboration, and external support.

Second, Open Innovation mechanisms are the practices through which knowledge, ideas, technologies, and resources circulate across organisational boundaries. These mechanisms include start-up engagement, research partnerships, public–private projects, institutional intermediaries, open data initiatives, digital platforms, collaborative experimentation, training programmes and Blue Economy projects. The reviewed cases indicate that these mechanisms vary according to the institutional configuration of each port ecosystem. In Rotterdam, Open Innovation is expressed through distributed experimentation; in Valencia, through institutional intermediation; in Barcelona, through smart-port and business-model innovation; in Motril-Granada, through territorial and Blue Economy collaboration; and in Baltic ports, through capacity-building and cross-border learning.

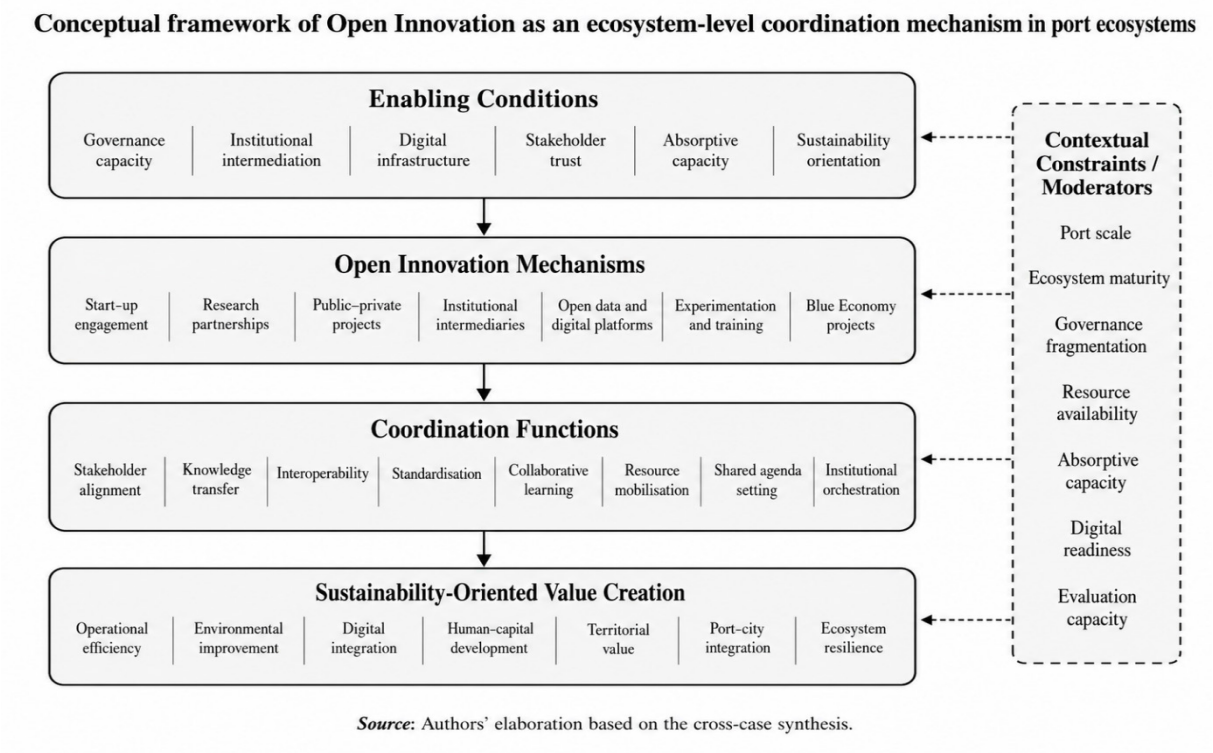
Third, coordination functions are the processes through which Open Innovation contributes to the alignment of actors, resources, standards, technologies, and objectives. In this framework, coordination is not treated as a general synonym for collaboration. Rather, it refers to the specific alignment processes that allow heterogeneous actors to act collectively around innovation and sustainability challenges. These functions include stakeholder alignment, knowledge transfer, interoperability, standardisation, collaborative learning, resource mobilisation, shared agenda setting and institutional orchestration.

Fourth, sustainability-oriented value creation refers to the outcomes that may emerge when Open Innovation mechanisms successfully support coordination. These outcomes include operational efficiency, environmental improvement, digital integration, human-capital development, territorial value, port-city integration, ecosystem resilience and long-term sustainable transformation. The framework therefore distinguishes between coordination as a process and value creation as an outcome. Open Innovation creates value not simply because actors collaborate, but because collaboration enables the alignment of knowledge, resources, infrastructures and strategic objectives across the ecosystem (De Martino, 2021; Tsvetkova & Hellström, 2022).

The framework also recognises that Open Innovation is constrained by several barriers. These include fragmented governance, a limited culture of innovation, weak standardisation, low absorptive capacity, resource scarcity, uneven digital maturity, a lack of evaluation frameworks, and difficulties in scaling innovation beyond individual projects. These constraints influence whether Open Innovation remains a set of isolated initiatives or becomes a systemic coordination mechanism. In this sense, the framework interprets Open Innovation as a mediating process between ecosystem conditions and sustainability-oriented value creation.

The proposed framework is presented in Figure 1.

Figure 1. Conceptual framework of Open Innovation as an ecosystem-level coordination mechanism in port ecosystems



Source: Authors' elaboration based on the cross-case synthesis

The proposed framework illustrates that Open Innovation does not inherently lead to sustainability-oriented value creation. Instead, its contribution is contingent upon the extent to which Open Innovation mechanisms fulfil coordination functions within a given port ecosystem. Enabling conditions influence the availability and effectiveness of these mechanisms, while contextual constraints moderate the progression from isolated collaboration to ecosystem-level coordination. Consequently, the framework provides a clear analytical distinction among the mechanisms facilitating knowledge circulation, the coordination functions aligning actors and resources, and the potential forms of value creation resulting from this alignment.

This distinction is important for port ecosystems because they involve multiple actors, including port authorities, terminal operators, shipping companies, logistics providers, technology firms, research institutions, public agencies and local communities. Therefore, innovation depends not only on technology adoption, but also on the capacity to coordinate interdependent stakeholders around shared goals, interoperable systems and sustainability-oriented transformation pathways.

The framework also provides a basis for future empirical testing. It suggests that governance capacity, institutional intermediation, digital infrastructure, absorptive capacity, and port scale may influence the extent to which Open Innovation mechanisms coordinate and generate sustainability-oriented value. These relationships are not treated here as empirically validated hypotheses, but as conceptual propositions derived from the cross-case synthesis. They are further discussed in Section 5.6 as directions for future research.

5. DISCUSSION

5.1. OPEN INNOVATION AS AN ECOSYSTEM-LEVEL COORDINATION MECHANISM

The cross-case synthesis supports the interpretation of Open Innovation as an ecosystem-level coordination mechanism in port ecosystems. This interpretation extends the traditional firm-centred understanding of Open Innovation, which emphasises purposive knowledge flows across organisational boundaries, towards a broader ecosystem perspective in which innovation depends on the alignment of multiple interdependent actors, resources, infrastructures and objectives (Chesbrough, 2003; Chesbrough & Bogers, 2014; Adner, 2017; Bogers et al., 2018; West & Bogers, 2017). In this sense, Open Innovation in port ecosystems should not be understood merely as the adoption of external ideas, the creation of start-up programmes or the presence of collaborative projects. Rather, its strategic relevance lies in its capacity to structure interaction, mobilise distributed knowledge and support collective action across organisations that are operationally interdependent but institutionally heterogeneous.

This distinction is particularly important in port ecosystems. Ports are complex socio-technical systems in which innovation involves port authorities, terminal operators, shipping companies, logistics providers, technology firms, public agencies, research institutions and local communities. These actors differ in mandates, resources, strategic priorities and time horizons. As a result, innovation cannot be reduced to isolated technological adoption or bilateral collaboration. It requires coordination mechanisms capable of aligning standards, data infrastructures, investment priorities, regulatory requirements, operational routines and sustainability objectives. The reviewed literature on smart ports, port governance and digital transformation confirms that innovation adoption in ports depends heavily on interoperability, co-opetition, institutional capacity and multi-actor coordination (de Langen et al., 2020; Roumboutsos et al., 2022; Tijan et al., 2021; Vanelslander et al., 2019).

The proposed framework therefore clarifies the analytical difference between Open Innovation mechanisms, coordination functions and sustainability-oriented value creation. Open Innovation mechanisms refer to the practices through which knowledge and resources circulate across organisational boundaries, such as research partnerships, institutional intermediaries, public–private projects, digital platforms, start-up engagement and collaborative experimentation. Coordination functions refer to what these mechanisms do within the ecosystem: they align actors, enable knowledge transfer, support interoperability, mobilise resources, facilitate standardisation and create shared agendas. Sustainability-oriented value creation refers to the outcomes that may result from such coordination, including operational efficiency, environmental improvement, human-capital development, territorial value, port-city integration and ecosystem resilience (De Martino, 2021; Tsvetkova & Hellström, 2022).

This distinction helps address a recurring ambiguity in literature. Collaboration is often treated as inherently beneficial, but collaboration alone does not necessarily generate innovation, coordination or sustainable value. Similarly, digital infrastructure may enable information exchange, but it does not automatically produce collective action. Open Innovation becomes a coordination mechanism only when knowledge flows, collaborative arrangements and boundary-spanning interactions are connected to shared objectives, governance structures and ecosystem-level capabilities. In this sense, the contribution of Open Innovation lies not simply in opening organisational boundaries, but in transforming openness into organised interaction, collective learning and coordinated transformation.

The cross-case synthesis also suggests that this coordination role varies according to ecosystem configuration. In large and mature ports, Open Innovation may support coordination by connecting experimentation, digital infrastructure and strategic innovation agendas. In intermediary-led ecosystems, it may operate through knowledge transfer, applied research and institutional orchestration. In smaller or resource-constrained ports, its coordination function may depend more strongly on capacity-building, absorptive capacity, territorial collaboration and external support. Therefore, Open Innovation should not be interpreted as a universal model that operates in the same way across all port ecosystems. Its effectiveness depends on the institutional, technological and organisational conditions through which openness is converted into coordination.

Overall, this interpretation advances the debate on Open Innovation in port ecosystems by shifting attention from the presence of collaborative initiatives to the functions those initiatives perform. The central issue is not whether a port ecosystem is "open" in a general sense, but whether Open Innovation mechanisms help coordinate actors, infrastructures and sustainability objectives in ways that support systemic transformation. This provides the conceptual basis for understanding Open Innovation as a coordination mechanism and prepares the discussion of how different governance configurations shape this process.

5.2. GOVERNANCE CONFIGURATIONS AND INSTITUTIONAL INTERMEDIATION

The cross-case synthesis shows that Open Innovation in port ecosystems is strongly shaped by governance configurations. Because ports are multi-actor systems involving public authorities, private operators, logistics firms, technology providers, research organisations and public agencies, innovation does not depend only on the willingness of individual actors to collaborate. It also depends on the institutional arrangements through which collaboration is organised, priorities are negotiated, resources are mobilised and collective action is sustained. In this sense, governance provides the institutional setting within which Open Innovation mechanisms can perform coordination functions.

This finding is consistent with the ecosystem perspective on innovation, which emphasises that value creation depends on the alignment of interdependent actors rather than on the capabilities of a single organisation alone (Adner, 2017; Bogers et al., 2018; West & Bogers, 2017). It also resonates with port governance literature, which highlights the role of port authorities, institutional arrangements, public–private relationships and decision-making structures in shaping port development and innovation trajectories (de Langen et al., 2020; Vanelslander et al., 2019; Zhang et al., 2019). From this perspective, Open Innovation requires not only open boundaries, but also governance arrangements capable of converting dispersed knowledge into coordinated action.

The reviewed cases suggest that there is no single governance model for Open Innovation in port ecosystems. In distributed innovation ecosystems, such as Rotterdam, coordination depends on the ability to connect multiple innovation spaces, experimental initiatives, start-ups, public actors and private firms without reducing openness to fragmented experimentation. In intermediary-led ecosystems, such as Valencia, institutional intermediation plays a more central role by connecting port actors, research institutions, firms and public agencies through applied research, training, knowledge transfer and innovation projects. In smart-port pathways, such as Barcelona, governance is closely linked to strategic digital transformation, business model innovation and the integration of technological infrastructures with stakeholder coordination. In smaller or territorially embedded port ecosystems, such as Motril-Granada and small and medium-sized Baltic ports, governance is more closely associated with capacity-building, local collaboration,

Blue Economy strategies and regional development objectives.

These differences indicate that institutional intermediation can be a critical enabler of Open Innovation. Intermediaries can reduce coordination costs, translate knowledge across communities, support trust-building, connect actors with different capabilities and help transform isolated projects into more structured innovation processes. In port ecosystems, this role is particularly important because actors often have different mandates, operational constraints and strategic horizons. Port authorities may prioritise regulation, land use and long-term infrastructure development; terminal operators may focus on operational efficiency; logistics firms may seek service reliability and cost reduction; technology providers may emphasise digital solutions; and public agencies may prioritise compliance, sustainability and regional development. Intermediaries can help bridge these differences by creating shared spaces for experimentation, knowledge exchange and collaborative problem-solving.

However, institutional intermediation also has limits. When Open Innovation depends too heavily on a single intermediary or a small group of institutional actors, the ecosystem may become vulnerable to centralisation, project dependency or limited diffusion of innovation capabilities. In such contexts, coordination may remain concentrated in formal programmes rather than becoming embedded in the routines, relationships and absorptive capacities of the wider ecosystem. This suggests that effective governance of Open Innovation requires a balance between orchestration and distributed participation. Too little coordination may produce fragmentation, while excessive centralisation may reduce experimentation, ownership and ecosystem-wide learning.

The distinction between governance and coordination is therefore analytically important. Governance refers to the institutional arrangements, authority structures and decision-making settings through which innovation is organised. Coordination refers to the alignment processes through which actors, resources, technologies and objectives are connected in practice. Open Innovation operates between these two dimensions: it is enabled by governance arrangements, but it contributes to coordination only when collaborative mechanisms generate knowledge transfer, interoperability, shared agendas and collective learning. This distinction helps explain why similar Open Innovation mechanisms may produce different outcomes across port ecosystems.

For port authorities and ecosystem intermediaries, the implication is that Open Innovation should be governed as a systemic capability rather than as a portfolio of isolated initiatives. This requires structures that support continuity, trust, evaluation, knowledge retention and cross-organisational learning. It also requires attention to differences in ecosystem maturity. Large ports may need governance arrangements capable of integrating multiple innovation initiatives, while smaller and medium-sized ports may require stronger support for absorptive capacity, skills development and regional collaboration. Thus, governance configurations shape not only whether Open Innovation occurs, but also whether it becomes a durable coordination mechanism capable of supporting sustainability-oriented transformation.

5.3. DIGITAL INFRASTRUCTURES, STANDARDS AND THE LIMITS OF TECHNOLOGY-LED INNOVATION

Digital infrastructure plays an important role in Open Innovation processes within port ecosystems, but the cross-case synthesis suggests that its contribution should not be interpreted deterministically. Technologies such as Port Community Systems, smart-port platforms, Internet of Things applications, blockchain, digital twins and data-sharing systems can facilitate information exchange, improve visibility and support interoper-

ability. However, they do not automatically generate coordination, collaboration or sustainability-oriented value creation. Their relevance depends on how they are embedded in governance arrangements, stakeholder relationships, standards and shared innovation objectives (Tijan et al., 2021; Roumboutsos et al., 2022; Vanelslander et al., 2019).

Port Community Systems, 5G applications and Open Innovation 4.0 approaches illustrate that digital technologies may support competitiveness, efficiency and sustainability, but only when technical deployment is connected to stakeholder adoption, process integration and systemic innovation capabilities (Carlan et al., 2016; Cavalli et al., 2021; Costa & Matias, 2020).

This distinction is important because smart-port literature often emphasises technological capabilities, while the governance and organisational conditions required for their effective use may receive less attention. Digital tools can reduce transaction costs, improve operational transparency and enable new forms of data-driven collaboration, but they may also reproduce fragmentation if actors do not share standards, incentives, trust or decision-making frameworks. In this sense, digital infrastructure should be understood as a coordination enabler rather than as a substitute for ecosystem governance.

Comparative analysis indicates that digitally advanced port ecosystems are better positioned to experiment with data-driven innovation, but digital maturity alone is insufficient. Large ports may possess advanced technological infrastructures, yet still face challenges related to interoperability, stakeholder alignment and the integration of multiple innovation initiatives. Conversely, smaller and medium-sized ports may lack advanced digital infrastructures but can still develop Open Innovation through capacity-building, collaborative learning and territorial partnerships. Therefore, the coordination function of Open Innovation depends not only on the technological sophistication of the ecosystem, but also on the capacity to connect digital tools with institutional arrangements and collective objectives.

This finding reinforces the need to avoid a technology-driven interpretation of port innovation. Digitalisation can support Open Innovation when it enables knowledge flows, shared visibility, interoperability and collaborative decision-making across the ecosystem. However, when digital projects remain isolated, vendor-driven or disconnected from governance structures, their capacity to generate systemic transformation is limited. The key issue is therefore not whether ports adopt digital technologies, but whether these technologies become part of coordinated innovation processes that align actors, resources and sustainability goals.

From this perspective, digital infrastructure occupies an intermediate position in the proposed framework. It is both an enabling condition and, in some cases, an Open Innovation mechanism. As an enabling condition, it provides the technical basis for connectivity and data exchange. As an Open Innovation mechanism, it can support collaborative experimentation, open data initiatives and digital platforms for stakeholder interaction. Nevertheless, its contribution to sustainability-oriented value creation depends on whether it performs coordination functions such as interoperability, standardisation, knowledge transfer and shared agenda setting.

Thus, the main implication is that port digitalisation should be governed as part of an ecosystem-level innovation strategy rather than as a set of isolated technological upgrades. For port authorities, intermediaries and policy actors, this means linking digital investment to governance capacity, stakeholder engagement, data-sharing rules, skills development and evaluation mechanisms. Without these conditions, digital infrastructure may improve specific operations but fail to support broader Open Innovation and sustainable port transformation.

5.4. SUSTAINABLE VALUE CREATION AS A COORDINATED OUTCOME

The cross-case synthesis also clarifies the relationship between Open Innovation, coordination and sustainability-oriented value creation. In port ecosystems, value creation should not be understood only in economic or operational terms. Because ports operate as logistics infrastructures, business networks, territorial interfaces and environmental pressure points, value creation includes multiple dimensions, such as operational efficiency, environmental performance, digital integration, knowledge development, human-capital formation, port-city relations, territorial development and ecosystem resilience (De Martino, 2021; Tsvetkova & Hellström, 2022).

This broader understanding is also consistent with research on open eco-innovation, port-city relations and Sustainable Development Goals in maritime and port sectors, which shows that value creation increasingly involves environmental, territorial, social and governance-related dimensions rather than only operational or economic performance (Garcia et al., 2019; Jansen & Hein, 2023; Diniz et al., 2023).

This multidimensional view is consistent with the broader literature on sustainable and ecosystem-based innovation, which emphasises that innovation outcomes increasingly depend on the capacity to generate value beyond the boundaries of a single firm or organisation (Adner, 2017; Bogers et al., 2018; West & Bogers, 2017). In port contexts, this is particularly relevant because no single actor controls all the resources, infrastructures, data flows or decision-making arenas required for sustainable transformation. Port authorities, terminal operators, logistics firms, technology providers, public agencies, research institutions and local communities contribute different resources and pursue different objectives. Sustainable value creation therefore depends on the ability to align these heterogeneous contributions through coordinated innovation processes.

The distinction between coordination and value creation is central to this paper's argument. Coordination refers to the process through which actors, resources, standards, technologies and sustainability objectives are aligned. Value creation refers to the outcomes that may result from this alignment. Open Innovation becomes relevant not simply because it increases the number of collaborations or external knowledge flows, but because it can transform dispersed knowledge and fragmented initiatives into coordinated action. In this sense, sustainability-oriented value creation is not an automatic consequence of openness; it depends on whether Open Innovation mechanisms perform coordination functions such as stakeholder alignment, interoperability, collaborative learning, resource mobilisation and shared agenda setting.

The reviewed cases suggest that sustainability-oriented value creation takes different forms according to the configuration of each port ecosystem. In more digitally advanced and mature ecosystems, value creation may be associated with smart-port integration, energy transition, data-driven logistics and business model innovation. In intermediary-led ecosystems, it may be expressed through knowledge transfer, applied research, skills development and institutionalised collaboration. In smaller or resource-constrained ports, it may depend more strongly on capacity-building, territorial collaboration, Blue Economy positioning and regional resilience. These differences show that sustainable value creation is context-dependent and mediated by governance capacity, absorptive capacity, digital readiness and ecosystem maturity.

This interpretation also cautions against treating sustainability as a generic or symbolic objective. Open Innovation contributes to sustainability only when collaborative mechanisms are connected to concrete coordination functions and evaluable outcomes. Without such alignment, sustainability initiatives may remain fragmented, project-based or disconnected from operational and territorial transformation. Therefore, port ecosys-

tems need not only sustainability ambitions but also mechanisms to translate those ambitions into coordinated innovation practices, shared metrics, and long-term ecosystem capabilities.

The main implication is that sustainable port transformation requires more than technological adoption or stakeholder participation. It requires the orchestration of knowledge flows, institutional arrangements, digital infrastructures and strategic objectives in ways that generate collective value. From this perspective, Open Innovation acts as a bridge between dispersed ecosystem resources and sustainability-oriented outcomes. Its contribution lies in enabling port ecosystems to move from isolated initiatives towards coordinated forms of value creation that are operationally effective, environmentally meaningful and territorially embedded.

5.5. THEORETICAL AND PRACTICAL IMPLICATIONS

This study has three main theoretical implications. First, it contributes to Open Innovation literature by extending the concept from a firm-centred knowledge-flow perspective to an ecosystem-level coordination perspective. While the foundational literature emphasises the purposive use of internal and external knowledge flows across organisational boundaries (Chesbrough, 2003; Chesbrough & Bogers, 2014), the analysis developed in this paper suggests that, in port ecosystems, the central issue is not only whether knowledge crosses organisational boundaries, but whether such knowledge flows help align interdependent actors, resources, digital infrastructures and sustainability objectives. This reframing contributes to the broader ecosystem view of innovation, in which value creation depends on actor interdependence, complementarity and alignment rather than on the capabilities of a single organisation alone (Adner, 2017; Bogers et al., 2018; West & Bogers, 2017).

Second, the study contributes to the port innovation and governance literature by clarifying the distinction among governance arrangements, coordination functions, and value-creation outcomes. Governance refers to the institutional setting through which innovation is organised; coordination refers to the alignment processes by which actors, standards, infrastructures, and objectives are connected; and value creation refers to the outcomes generated by this alignment. This distinction is relevant because port innovation is often discussed in terms of overlapping concepts such as collaboration, digitalisation, smart-port development, governance, and sustainability. By analytically separating these dimensions, the paper provides a clearer conceptual basis for examining how Open Innovation operates within port ecosystems.

Third, the proposed framework contributes to research on sustainable port transformation by showing that sustainability-oriented value creation is not an automatic result of openness, collaboration or digitalisation. Rather, it depends on whether Open Innovation mechanisms perform coordination functions within specific ecosystem conditions. This interpretation helps explain why similar innovation practices may produce different outcomes across ports with different levels of digital maturity, governance capacity, absorptive capacity and institutional intermediation. It also reinforces the need to examine Open Innovation as a context-dependent process shaped by port scale, ecosystem maturity, governance fragmentation and resource availability.

The practical implications are also significant. For port authorities, the findings suggest that Open Innovation should not be managed merely as a set of isolated projects, pilot initiatives or technology partnerships. Instead, it should be treated as a systemic capability for coordinating actors, infrastructures and sustainability objectives across the port ecosystem. This requires port authorities to act not only as landlords, regulators or infrastructure managers, but also as facilitators of knowledge exchange, interoperability,

stakeholder alignment and long-term innovation learning.

For innovation intermediaries, the study highlights the importance of bridging functions. Intermediaries can support Open Innovation by connecting firms, port authorities, research institutions, technology providers and public agencies; translating knowledge across organisational and disciplinary boundaries; reducing coordination costs; and supporting the continuity of collaborative projects. However, intermediation should not lead to excessive centralisation. Its value lies in enabling distributed participation, strengthening absorptive capacity and embedding innovation capabilities across the wider ecosystem.

For regional and policy actors, this also connects port Open Innovation with broader debates on maritime clusters, knowledge-intensive service activities, smart specialisation and quadruple- or quintuple-helix innovation ecosystems, where sustainable transformation depends on interaction among industry, government, academia, civil society and territorial actors (Monteiro, 2016; Gifford & McKelvey, 2019; Carayannis et al., 2021)

Finally, the study has implications for how port ecosystems evaluate innovation. If Open Innovation is understood as a coordination mechanism, then evaluation should not focus only on the number of projects, partnerships or technologies adopted. It should also assess whether innovation initiatives improve interoperability, stakeholder alignment, collaborative learning, resource mobilisation and sustainability-oriented value creation. This broader evaluation perspective can help port ecosystems move from fragmented initiatives towards more systemic and durable forms of innovation governance.

5.6. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This study has several limitations that should be acknowledged. First, it is based on secondary evidence and does not include primary empirical data such as interviews, surveys, direct observation or longitudinal fieldwork. As a result, the analysis depends on the availability, depth and methodological quality of the reviewed literature. The findings should therefore be interpreted as an analytical synthesis of existing evidence rather than as direct empirical validation of Open Innovation practices in the selected port ecosystems.

Second, the selected cases differ in evidential depth, institutional maturity, geographical context and port scale. Rotterdam, Valencia and Barcelona are more extensively documented in the literature, whereas Motril-Granada and small and medium-sized Baltic ports are represented through more focused or aggregated evidence. This asymmetry limits direct comparison between cases. However, the objective of the study was not to rank ports or produce statistically representative findings, but to identify analytically distinct Open Innovation configurations and explore how they operate under different ecosystem conditions.

Third, the proposed framework should be understood as a conceptual contribution rather than as a validated causal model. It identifies possible relationships between enabling conditions, Open Innovation mechanisms, coordination functions, contextual constraints and sustainability-oriented value creation. However, these relationships require further empirical examination. Future studies could test and refine the framework through comparative case studies, interviews with port authorities and ecosystem actors, surveys, longitudinal analysis or mixed-methods research.

Future research could examine the conceptual relationships proposed in Figure 1. In particular, the following propositions may guide future empirical studies:

P_1. Governance capacity and institutional intermediation

The stronger the governance capacity and institutional intermediation within a port ecosystem, the more likely Open Innovation mechanisms are to support stakeholder alignment, knowledge transfer and collaborative learning.

P_2. Digital infrastructure and coordination

Digital infrastructure contributes to Open Innovation only when it is embedded in governance arrangements, interoperability standards and shared innovation objectives.

P_3. Absorptive capacity and knowledge mobilisation

Port ecosystems with higher absorptive capacity are more likely to transform external knowledge into coordinated innovation practices and sustainability-oriented outcomes.

P_4. Scale and capacity-building

In smaller and medium-sized ports, Open Innovation is more dependent on capacity building, human capital development, and cross-border learning than on advanced digital infrastructure alone.

P_5. Coordination and sustainable value creation

Sustainability-oriented value creation emerges when Open Innovation mechanisms support coordination functions such as stakeholder alignment, collaborative learning, resource mobilisation, interoperability, and shared agenda-setting.

P_6. Barriers to systemic transformation

Governance fragmentation, limited resources, weak standardisation, and insufficient evaluation frameworks reduce Open Innovation's capacity to move from isolated projects to ecosystem-level transformation.

These propositions are not presented as empirically tested hypotheses, but as analytical relationships derived from the cross-case synthesis. They provide a basis for future research to examine how Open Innovation operates across different types of port ecosystems and under different institutional, technological and territorial conditions. Future empirical work could also compare large hub ports, intermediary-led ecosystems, smart-port strategies, and smaller resource-constrained ports to assess how governance capacity, digital readiness, and absorptive capacity affect the transition from isolated innovation initiatives to ecosystem-level coordination.

Finally, future research should develop more robust evaluation frameworks for Open Innovation in port ecosystems. Existing studies often describe collaborative projects, digital initiatives or sustainability strategies, but less frequently assess whether these initiatives generate measurable coordination effects or long-term ecosystem capabilities. Further research could therefore examine indicators such as interoperability, stakeholder alignment, knowledge retention, collaborative learning, resource mobilisation, environmental outcomes, port-city value and ecosystem resilience. Such work would help move the field from descriptive accounts of innovation initiatives towards stronger empirical assessment of Open Innovation as a coordination mechanism for sustainable port transformation.

6.CONCLUSION

This study examined how Open Innovation is operationalised as a coordination mechanism in European port ecosystems. Drawing on a semi-structured literature review and qualitative cross-case comparative synthesis, the paper analysed five Open Innovation configurations: distributed experimentation in Rotterdam, institutional intermediation in Valencia, smart-port and business-model innovation in Barcelona, Blue Economy and territorial innovation in Motril-Granada, and capacity-building in small and medium-sized Baltic ports.

The main contribution of the study is the conceptualisation of Open Innovation as an ecosystem-level coordination mechanism. Rather than treating Open Innovation merely as collaboration, external knowledge sourcing or technology adoption, the paper shows that its relevance in port ecosystems lies in its capacity to align heterogeneous actors, re-

sources, digital infrastructures, standards and sustainability objectives. This distinction clarifies the relationship between Open Innovation mechanisms, coordination functions and sustainability-oriented value creation.

The proposed conceptual framework contributes to the literature by explaining how enabling conditions, Open Innovation mechanisms and coordination functions may interact to support sustainable port transformation. It also highlights that Open Innovation is context-dependent: its effectiveness is shaped by governance capacity, institutional intermediation, absorptive capacity, digital readiness, port scale and ecosystem maturity. Therefore, openness should not be understood as inherently beneficial, but as valuable when it is converted into organised interaction, collective learning and coordinated action.

The study is limited by its reliance on secondary evidence and by the unequal evidential depth of the selected cases. The proposed framework should therefore be interpreted as an analytical contribution rather than as an empirically validated causal model. Future research should test and refine the framework through primary empirical studies, comparative port research, longitudinal analyses, and mixed methods designs to assess how Open Innovation contributes to coordination, sustainable value creation, and ecosystem resilience across different port contexts.

Declaration of generative ai and ai-assisted technologies in the writing process

During the preparation of this work, the author(s) used app.litmaps.com to visualise how papers relate to one another and to discover relevant new papers. We also used Scite.ai and SciSpace.ai to organise and chat with the documents, getting answers and explanations. After using these tools/services, the author(s) reviewed and edited the content as needed and take full responsibility for the publication's content.

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