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OCEAN AND SOCIETY

Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions

Edited by Mina Akhavan, Yvonne van Mil, and Carola Hein

Volume 2

2025

Open Access Journal

ISSN: 2976-0925

Ocean and Society, 2025, Volume 2
Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions

Published by Cogitatio Press
Rua Fialho de Almeida 14, 2° Esq.,
1070–129 Lisbon
Portugal

Design by Typografia®
http://www.typografia.pt/en/

Cover image: © MAGNIFIER from iStock

Available online at: www.cogitatiopress.com/oceanandsociety

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https://doi.org/10.17645/oas.10067

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EDITORIAL

Open Access Journal

Global Maritime Flows and Local Implications: Conceptualising a Worldwide Taxonomy and Glossary of Port-City-Regions

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Submitted: 6 February 2025 **Published:** 26 February 2025

Issue: This editorial is part of the issue "Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions" edited by Mina Akhavan (TU Delft), Yvonne van Mil (TU Delft), and Carola Hein (TU Delft), fully open access at https://doi.org/10.17645/oas.i442

Abstract

The dynamic interplay between global maritime flows and the spatial, economic, and social development of port-city-regions lies at the heart of this thematic issue. As globalisation accelerates, the relationships between ports, cities, and their surrounding regions become increasingly complex, requiring innovative conceptual frameworks, methodologies, and interdisciplinary collaborations to address both challenges and opportunities. Flows of goods and people shape infrastructural networks and create nodes of logistics and administration in and around nearby cities. They establish specific networks that primarily facilitate transport. Multiple approaches and definitions exist to describe and map these unique spaces. This thematic issue of *Ocean and Society* aims to advance our understanding of these phenomena by exploring a range of terminologies, typologies, spatial transformations, and examples of sustainable practices across diverse geographic contexts.

Keywords

data; global maritime activities; mapping; port-city interface; port-city planning; sustainability; transition

1. Navigating Port-City-Regions in Transition

Many port cities across the globe have long thrived on maritime flows and trade connections, leveraging their strategic locations to drive socio-spatial and economic growth. Ports functioning as gateways and hubs have historically been of key importance for local economies and spatial development (Akhavan, 2020; Hein, 2011). However, with the advent of the Industrial Revolution and technological advancements, such as containerisation and innovation in the shipping industry, the dynamic between ports and cities has been undergoing significant changes. Port regions have become central hubs for shipping, cargo handling and

related industries, playing a pivotal role in regional and global economies and trade networks (Akhavan, 2023). While they are often governed by separate entities—port authorities and municipalities or city councils as well as other governmental and corporate entities—ports and cities remain closely intertwined in terms of spatial connectivity and shared interests in the port-city interface spaces (Hein et al., 2023). Yet, as ports continue to influence and shape urban landscapes, there is a pressing need to introduce new tools and perspectives to understand how global flows through maritime infrastructures reshape the built environment.

As port regionalization progresses—shaping the influence of ports on their surrounding territories—the reach of port-related activities grows increasingly complex and expansive (Hesse, 2018). The spatial impact of the flows of goods and people on nearby cities and territories creates a unique spatial imprint, a port-city territory that is not congruent with administrative borders (Hein, 2011). Multiple patterns of port-city territory interaction emerge that merit classification and analysis as they result in different challenges related to spatial planning, governance, or sustainable development (Hein et al., 2023). Small ports adjacent to large cities or large ports without urban neighbours and open hinterlands create different spatial patterns, each with their respective requirements and challenges regarding hinterland infrastructures, logistics centres, or land use. Therefore, fostering dialogue and collaboration among stakeholders in ports, cities, and adjacent regions becomes imperative. Many researchers aim to capture these patterns, creating a broad range of terminologies and applying multiple methodologies. These frameworks also provide fundamental insights for the sustainable design of these territories.

Maritime transport is a catalyst for urban and regional development. Still, it also brings negative externalities to urban and rural or sparsely populated environments, such as pollution, congestion, and noise (Acciaro et al., 2014). Addressing these challenges is vital for sustainable port, city, and regional development. Growing environmental awareness has encouraged efforts toward sustainable port operations and increased marine traffic, resulting in increased projects for green ports, blue growth, and green corridors. With these discussions come a proliferation of new concepts, terminologies, and tools to bridge the gap among research, planning, policy, and practice.

This thematic issue seeks to advance the conceptual, theoretical, and empirical discussion around the spatiality of port(s) and their hosting cities in different regions of the world. The aim is to contribute to the large body of literature by identifying the territorial typology of port cities and their regions, starting from the global flows from the sea (commodity, passengers, and knowledge) that run through maritime and inland ports and create a complex ecosystem.

2. Key Themes and Contributions

The five articles in this thematic issue address critical dimensions of global maritime flows and their local impact in port-city-regions from various disciplinary perspectives and explore how this complex interaction between land and sea shapes the spatial, economic, social, and environmental aspects of these regions, addressing several sub-themes:

1. The evolution of the relationship between ports, cities, and the region, as well as the new hierarchies of spaces shaped by maritime flows at the port-city interface and within the wider region.

The two articles "Waterfront Redevelopment Five Decades Later: An Updated Typology and Research Agenda" by Enrico Tommarchi and "Investigating Port Spatiality: Tools for a Spatial Approach" by Beatrice Moretti demonstrate the evolution of ports and cities from highly interdependent entities to separate systems and offer perspectives on reshaping this relationship. Both articles introduce new terminologies and taxonomies of spatial impacts of ports on the surrounding landscape affected by the port or port-related activities, and vice versa. Tommarchi's article revisits the typologies of waterfront redevelopment in port cities and reflects on how contemporary approaches differ from the "port out, city in" rationale of past decades. He mentions the concept of "demaritimisation," where port activities are pushed out of the city centre, and the opposite, "remaritimisation," where the connection with the sea is strengthened. Tommarchi's contribution highlights the shift towards more sustainable and integrated planning strategies that balance economic, social, and environmental considerations. Drawing on examples from Europe and beyond, the study underlines the nuanced and evolving nature of port-city relations in the 21st century. Moretti's contribution focuses on "port regionalisation," where the impact of ports extends beyond their immediate surroundings and the need for more integrated spatial planning to manage these relationships. Using Italian case studies, a new terminology for spatial indicators is introduced to detect the presence, recurrence, and location of spatial impacts and address the complexities of clustered port governance and spatial optimisation.

2. Sustainable development of port regions and the role of institutions and multiplicity of stakeholders in shaping port-city-regions.

Sustainable development is a key focus of the contribution "Decarbonising Maritime Transport: The Role of Green Shipping Corridors in Making Sustainable Port-City Ecosystems" by Mina Akhavan, in which she discusses concepts such as "green ports," "blue growth," and "green corridors." Akhavan's article specifically discusses the implementation and challenges of green shipping corridors (GSCs), emphasising the importance of a holistic approach that includes both environmental and socio-economic aspects. By reviewing the state-of-the-art GSCs worldwide, she discusses the integration of renewable energy, alternative fuels, and electrification technologies, emphasising the transformative role of such corridors in achieving climate goals and redefining port-city ecosystem interactions.

3. Cultural heritage and identity: revisiting the concept of port-city relationship through the lens of new urban waterfront and urban regeneration.

Another theme explored is the role of "museumisation" and "performativity" in port-city regions in the article "Between Containers and Warehouses: Rehabilitating Port Proximities in UAE Coastal Cities" by Hiba Farhat and Ayman Kassem. Such approaches, aimed at preserving historical heritage and cultural identity, are seen as ways of countering the negative effects of globalisation. They can also contribute to the regeneration of urban areas around ports and the involvement of local communities. Using case studies from the United Arab Emirates, this article examines the socio-spatial impacts of rapid port modernisation and maritime capitalism. The study highlights the importance of sustainable urban recovery efforts that preserve heritage while promoting public access and active engagement in port-adjacent areas.

4. Data-driven research methods.

The article "A Data-Driven History of Gloucester's Fisheries Architecture" by Rafael Sousa Santos and André Tavares uses data-driven historical analyses to examine the development of fisheries and associated changes in the built environment. These analyses highlight the potential to complement existing knowledge and gain new insights by integrating statistical, geospatial, and historical data. With a mixed-method approach, the study provides a framework for analysing the environmental impacts of industrialised fisheries and their reflections in the built environment. It demonstrates the potential of data-driven methodologies to enhance our understanding of historical and contemporary port ecosystems.

In summary, the overarching theme of these articles is the complex interaction between global maritime activities and their local impacts, examining the port-city-regions as a dynamic and changing system. The articles highlight the need for an integrated and multidisciplinary approach to address the challenges and opportunities in these regions, focusing on sustainability, cultural heritage, spatial planning, and the involvement of local communities.

3. Looking Ahead

The contributions in this thematic issue not only provide a multidisciplinary understanding of the port-city-region nexus and its spatial impact but also highlight critical areas for future research. The evolution of port spatiality, the governance of clustered ports, the socio-cultural rehabilitation of port proximities, the integration of historical and environmental data, and the pursuit of maritime decarbonisation are all pivotal themes that demand further exploration. Together, these studies provide a foundation for developing sustainable, inclusive, and resilient port-city-regions in an era of transition and rapid global change.

We hope this collection inspires scholars, practitioners, and policymakers to engage with the complexities of port-city-region dynamics and contribute to shaping their sustainable futures.

Funding

This work was supported by Horizon.1.2—Marie Skłodowska-Curie Actions (MSCA), Project RePortFlows, under the Grant agreement ID: 101066680.

Conflict of Interests

The authors declare no conflict of interests.

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Ocean and Society
2025 • Volume 2 • Article 9265
https://doi.org/10.17645/oas.9265

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ARTICLE

Open Access Journal

Waterfront Redevelopment Five Decades Later: An Updated Typology and Research Agenda

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Submitted: 9 September 2024 **Accepted:** 26 November 2024 **Published:** 3 February 2025

Issue: This article is part of the issue "Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions" edited by Mina Akhavan (TU Delft), Yvonne van Mil (TU Delft), and Carola Hein (TU Delft), fully open access at https://doi.org/10.17645/oas.i442

Abstract

Since the second half of the twentieth century, when maritime practices began migrating outside their traditional central city areas, urban regeneration at the water's edge has been one of the key issues in port cities' planning agendas. Waterfronts in port cities have become strategic areas for a range of reasons, such as economic growth, city branding, and addressing housing pressures. However, recent studies also show how their transformation is now more profoundly influenced by hypermobile capital and global finance, and by broad sustainability concerns. The established narrative of waterfront redevelopment as a response to weakening port-city relationships no longer necessarily represents the present of all port cities, as more nuanced accounts are needed. With examples from Europe and across the world, this article reflects on waterfront redevelopment practices, by building on existing attempts to provide typologies and periodise the history of this phenomenon and focussing on the key approaches emerging in the last decades. It is argued that today's approaches to waterfront redevelopment, and ultimately contemporary relationships between ports and cities, are changing and possibly differentiating from the "port out, city in" rationale underpinning past schemes. Current practices appear to be ranging from the wholesale transformation of redundant waterfronts into neoliberal urban spaces for consumption and capital accumulation to more "fine-grained" planning strategies to build more (environmentally, but also economically, socially, and culturally) sustainable urban waterfronts by integrating or restoring port-related activities within mixed-used areas.

Keywords

port cities; port-city relationships; urban regeneration; waterfront redevelopment

1. Introduction

Many would agree that urban waterfronts are once again—albeit in a different way—the "shimmering theatre" of the world, as Meyer (1999, p. 32) described waterfronts in industrial port cities in the 19th century. After their decline due to port restructuring in the late 20th century, these areas have been bouncing back in economic but also symbolic terms (Hoyle & Pinder, 1992; R. Marshall, 2001; Porfyriou & Sepe, 2017). If it is true that waterfront redevelopment was a crucial issue for urban planning in the 1980s and 1990s (R. Marshall, 2001), its relevance seems to be undiminished today. Schemes currently being implemented such as Rotterdam's Makers District (Jansen et al., 2021) or the £5.5 billion Liverpool Waters project (P. Jones, 2015), as well as a range of experiences in developing countries (Furlan et al., 2019; H. Wang, 2014) show how waterfront redevelopment is set to shape planning agendas in the years to come. However, after about five decades since the first experiences in US cities, waterfront redevelopment processes are arguably changing and differentiating. On the one hand, this is linked to changing relationships between ports and cities (Wiegmans & Louw, 2011). If it is true that in the late 20th century, "ports disappeared from the minds and hearts of port city residents" (Jansen & Hein, 2023, p. 213) as traditional ties between ports and cities gradually dissolved, then different port-city relationships are emerging. We are witnessing a renewed interest from ports to be in the city (e.g., the central location of Rotterdam's World Port Center), and a return of industrial activities in post-Covid cities, port-related, or otherwise (Novy, 2022), such as compatible industrial activities or technology hubs. Therefore, port city scholars have no longer necessarily been asking how the takeover of urban port areas by expanding cities takes place, but whether it should take place (Daamen & Vries, 2013, p. 4). These trends are coupled with stronger sustainability concerns (Daamen & Vries, 2013; C. Evans et al., 2022; Fusco Girard et al., 2014) based on the recognition that urban waterfronts are very much exposed to the impacts of climate breakdown, but also that they are opportunities for cities to pursue all dimensions of sustainable development. On the other hand, one must acknowledge that the socio-economic and political framework in which waterfront redevelopment schemes now operate is not the same as that of the emerging globalisation and neoliberalism, or of large-scale public investment in waterfront regeneration, that characterised the 1980s and 1990s (Tommarchi & Jonas, 2024). Rather, such practices are happening in a socio-economic and political framework shaped by greater uncertainty (see Turnbull, 2022) and the immense power of hypermobile global capital (Rossi & Enright, 2018).

This article proposes an updated typology of approaches to waterfront redevelopment that complements existing frameworks—including periodisations reflecting on dominant approaches—by including experiences of waterfront redevelopment taking place in the last 25 years. An updated typology is needed to acknowledge the different contexts in which waterfront redevelopment as a process operates today and to categorise its more recent manifestations. Such a typology provides a common terminology for port city scholars and waterfront redevelopment specialists, which connects to the broader structural conditions in which these processes are taking place. The proposed typology distinguishes between tertiary-led, culture-led, event-led, late neoliberal, and holistic approaches. The first three typologies have already been identified in the literature, although with different terms (in the case of event-led approaches) or without an explicit acknowledgement of their connection to water or the area's maritime character (in the case of culture-led regeneration). Here, the article proposes a common terminology. Late neoliberal and holistic approaches are proposed in this article as new categories to interpret emerging waterfront redevelopment practices.

The article explores practices of waterfront redevelopment through an encompassing comparative strategy (Robinson, 2011; Tilly, 1984), which can be defined as a form of comparative analysis based on examining individual cases as manifestations of a broader structural process that is theoretically defined, and that serves as a framework to guide the analysis. This allows for exploring a range of cases of waterfront regeneration as instances of the same phenomenon—occurring globally (e.g., Brownhill, 2013)—of waterfront redevelopment under neoliberal capitalism, thereby establishing a mutual connection between the individual case and the structural process shaping it. This exercise is informed by the following methods. First, a review of the existing research on waterfront redevelopment, culture, and event-led regeneration on the waterfront. Second, desk research on the individual cases cited in Section 3, encompassing existing studies, policy documents available online, newspaper articles, and institutional websites. Third, further reflection on the findings of a research project undertaken by the author in 2016–2020, which included an in-depth analysis of event-led regeneration in Genoa, Rotterdam, and Valencia through policy analysis, semi-structured interviews with policymakers, senior civil servants, planners, experts and activists, street surveys, and non-participant observations (Tommarchi, 2022), and by the author's experience in the field.

The following Section 2 provides an overview of some of the existing attempts to categorise approaches to waterfront redevelopment. Many of these attempts look at the history of the phenomenon and therefore provide periodisations highlighting the dominant approach at one given time. Section 3 presents the typology of approaches proposed in this article, focussing on late neoliberal and holistic approaches as these are the new proposed categories. Section 4 outlines a research agenda stemming from the recognition of these two emerging typologies of approaches and in the light of the changing context in which waterfront redevelopment practices are likely to occur in the immediate future.

2. A Brief History of Waterfront Redevelopment

Urban port areas in central city locations—made redundant as a result of port restructuring taking place in the second half of the 20th century (Hoyle, 2000; Hoyle & Pinder, 1992; Hoyle et al., 1988)—have become strategic assets for real estate development and urban regeneration in many port cities (Hein, 2016; Ward, 2011). This section explores the key aspects of the process of waterfront redevelopment and gives an account of existing attempts to interpret its history through the identification of phases displaying common features. It is important to note that whilst such accounts focus on the periodisation of waterfront redevelopment as a global phenomenon, this article proposes a typology of common approaches (see Section 3).

Schubert (2008) outlines a generally applicable model of a transformation cycle at the interface between ports and cities to explain this phenomenon. The cycle starts with the abandonment of urban port areas due to the development of more modern port facilities outside the city. This leads to urban development visions for the transformation of these relatively central areas. Plans are implemented through the introduction of new uses (e.g., tertiary, housing, and leisure). Finally, new uses and facilities contribute to revitalising the area and increasing its appeal. Schubert's cycle successfully portrays how the redevelopment of waterfronts generally—albeit not exclusively—consists in the replacement of abandoned, or still partially working, port areas and structures with new urban amenities and uses, which port-related activities compete with for space (Hayuth, 1988). Through such a "port out, city in" strategy, former urban port areas are taken over by urban uses and transformed into what Breen and Rigby (1996) defined—depending on the predominant functions—as "commercial," "cultural educational and environmental," "historic," "recreational," "residential,"

or "working" waterfronts. Functions may include employment, housing (often in the upper sections of the market), recreational activities targeting the middle class, hospitality, culture, and heritage (Norcliffe et al., 1996).

There are several, slightly different periodisations of waterfront redevelopment (Table 1). Scholars acknowledge the origin of these practices in the pioneering experiences taking place in North American cities, starting from Baltimore, in the 1960s and 1970s. In the 1980s, the perceived success of initiatives in the US led to widespread attempts of replication through large-scale mixed-used schemes (Schubert, 2011) in other parts of the world, a phenomenon referred to as the Baltimore syndrome (Huang et al., 2007; Vallega, 2001) or the tragedy of such American-inspired attempts (Hajer, 1993). In the 1980s, waterfront redevelopment practices became widespread across European cities as well, including smaller cities and towns (Shaw, 2001), where mixed-use schemes (Andrade & Costa, 2020) included residential uses and public-led interventions (Shaw, 2001). European schemes present a variety of strategies such as tertiary-led (London Docklands), culture-led (Bilbao), or housing-led (Amsterdam, see Schubert, 2008). Hoyle (2000) sees this stage as a watershed between an initial phase of waterfront redevelopment that affirmed the separation between ports and cities, and a following phase starting in the 1980s where port-city links, including more symbolic ones, began to be reframed and retightened. Redundant urban waterfronts became tremendous opportunities to produce urban environments promoting contemporary—meaning post-industrial, neoliberal—values about urbanism, culture, and society (Malone, 1996; R. Marshall, 2001; Norcliffe et al., 1996; Vallega, 2001), often through urban spectacles celebrating the dynamism of port cities (Dovey, 2005; Tommarchi, 2024). Pagés Sánchez and Daamen (2020) argue that a global waterfront imaginary has begun to emerge as a result of these practices, as an assemblage of images and concepts that shape similar schemes around the world; and that these in turn strive to adhere to emerging expectations about the nature of these urban environments, leaving no room for port activities.

Table 1. Common phases of waterfront redevelopment identified in the literature.

Phases	Timeframe	Key features	Key literature
Pioneering initiatives in North America	1960s–1970s	Largely tertiary-led, similar functional and design features, and deregulated planning frameworks	Schubert (2008, 2011)
American-inspired experiences	1980s	Largely tertiary-led schemes in other parts of the world (drawing on American examples)	Schubert (2011); Vallega (2001)
European initiatives	1980s	Mixed-used developments, variety of strategies, retightening of port-city relationships, and smaller cities	Andrade and Costa (2020); Hoyle (2000); Shaw (2001)
Global waterfronts	1990s–Present	The growing role of globalisation and public-private partnerships	Fageir et al. (2021); Schubert (2008, 2011)
Mega-tertiary waterfronts	1990s–Present	Cultural/sporting mega-events as catalysts for change, large public investment, and physical transformation	Andrade and Costa (2020); Pinto and Lopes dos Santos (2022)

In commenting on waterfront redevelopment practices in the 1990s, scholars emphasise the different socio-economic context of that decade, marked by globalisation (Fageir et al., 2021), economic recession, and the need to rethink how resources were being used (Shaw, 2001), leading to the emergence of public-private partnerships (Schubert, 2011). Andrade and Costa (2020) introduce the idea of the "mega-tertiary waterfront" to describe large-scale redevelopments in the 1990s triggered by major/mega events such as the Olympic Games, highlighting that such schemes aimed at regenerating the city as a whole. They see a continuation of this phase into the 21st century, with attempts to retain port activities, thereby questioning the established "port out, city in" model, for example through a growing relevance of cruise tourism.

By drawing on these periodisations of waterfront redevelopment practices, Section 3 moves from a chronological categorisation to a typology of approaches, which highlights the key aspects of common strategies behind these processes of urban transformation.

3. An Updated Typology of Approaches to Waterfront Redevelopment

With more than 50 years of experience around the world and in a changing socio-economic and political context, it is perhaps time to reflect on the typology of approaches to waterfront redevelopment, looking at relatively recent examples. The proposed typology (Table 2) should be intended as a guide to explore different strategies of waterfront redevelopment in the last decades. The typology focuses on dominant approaches guiding the transformation of the waterfront. Three categories are drawn up, based on the existing studies explored in Section 2. Two further categories are proposed in this article and are identified on the basis of the similarities across recent cases of waterfront redevelopment. First, tertiary-led approaches are identified as based on the provision of tertiary functions. Second, culture-led approaches encompass waterfront redevelopment strategies levering the role of culture in urban regeneration. Third, event-led approaches include strategies based on harnessing the transformative power of cultural or sporting major or mega events, regardless of the functions introduced on the waterfront. Fourth, late neoliberal approaches are identified as rent-seeking strategies that focus on maximising the value that can be extracted from urban spaces and assets. Finally, holistic approaches are identified as more balanced strategies focussing on a range of dimensions of sustainability. Each approach arguably had or is having its heyday in the indicative timeframe mentioned. However, these approaches do coexist through time. Mixed approaches are not uncommon, and different strategies may be visible within the long-term redevelopment of waterfront areas in the same city as well. For example, port cities such as Barcelona or Liverpool display several of the approaches discussed in this section (Fageir et al., 2021; Ferreira & Visser, 2007).

3.1. Tertiary-Led

Waterfront redevelopment practices in the 1980s tended to be dominated by property-led and tertiary-led approaches, which emerged in a context of largely deregulated planning frameworks (Schubert, 2008). The transformation of the waterfront tended in these cases to target companies and investors, embracing the mantra "if we build it, they will come." These schemes were profoundly influenced by previous experiences in the US and were dominated by a "port out, city in" rationale. The key functions introduced on the waterfront were office blocks, retail facilities, and (predominantly luxury) housing. The regeneration of Canary Wharf in London (Gordon & Warren, 2022) is a prominent example, where the Enterprise Zone

Table 2. Dominant approaches to waterfront redevelopment since the 1980s.

Typology (approach)	Prevalent in	Key features	Promoter	Examples
Tertiary-led	1980s–1990s	Commercial and retail uses	Public-private partnerships	Buenos Aires (Puerto Madero) Cape Town (Victoria and Alfred Waterfront) London (Canary Wharf) Luanda (Baia de Luanda) Rotterdam (Kop van Zuid)
Culture-led	1980s–2000s	Flagship cultural facilities and public space	State/local authorities	Bilbao Dundee (Central Waterfront) Liverpool (Albert Dock, Mann Island) Newcastle-Gateshead (Quayside) Rotterdam (Museum Triangle)
Event-led	1990s–2010s	Large-scale transformation and (problematic) reuse of event facilities	State/local authorities	Barcelona (Port Vell, Port Olímpic, and Parc del Fòrum) Genoa (Porto Antico) Qingdao (Olympic Sailing Centre) Rio de Janeiro (Porto Maravilha) Shanghai (Expo area, 2010) Valencia (Port America's Cup)
Late neoliberal	2000s–2020s	Entertainment venues, retail and hospitality, and luxury housing	Private sector	Barcelona (Diagonal Mar) Belgrade Jeddah (Corniche) Liverpool (Kings Dock, Liverpool Waters) London (Vauxhall, Nine Elms, and Battersea) Newcastle (Giants on the Quayside)
Holistic	2000s–2020s	Attention to sustainability and attempts to re-integrate port and/or industrial activities	Public-private partnerships	Hamburg (HafenCity) Rotterdam (Makers District) Trieste (Porto Vivo)

Note: Information about examples from: Andreatta and Herce (2012); Bailey et al. (2004); Camerin (2019); Comune di Trieste (n.d.); Croese (2016); den Hartog (2021); Doucet (2013); Fageir et al. (2021); Ferreira and Visser (2007); Gordon and Warren (2022); Hajer (1993); Jansen et al. (2021); Koelemaij (2021); Larco (2009); T. Marshall (2004); Martinez Perez and Sanz (2022); Mostafa (2017); Schubert (2020); Smith et al. (2016); Tommarchi (2023); X. Wang (2021).

regime facilitated the development of what is today one of London's key business districts. Another example is Rotterdam's Kop van Zuid (Figure 1), initially planned as a housing-led redevelopment and later reframed as a mixed-used regeneration scheme led by tertiary functions (Doucet, 2013). These schemes have been criticised for their similar characteristics and aesthetics (e.g., Norcliffe et al., 1996; Schubert, 2008), each shaped by flows of capital (Malone, 1996) and planning ideas (Ward, 2011) across deregulated planning frameworks such as the Enterprise Zone regime mentioned above, in an increasingly neoliberal economy.

Figure 1. Kop van Zuid in Rotterdam.

Although prevalent in the 1980s, variations of tertiary-led approaches are visible in more recent schemes that focus on the provision of office space and the use of ultramodern architecture (e.g., Baia de Luanda; see Croese, 2016).

3.2. Culture-Led

Culture-led urban regeneration is a form of urban regeneration where cultural activity is the catalyst for transformation (G. Evans & Shaw, 2004). The culture-led transformation of waterfronts (as underlined by Schubert, 2008) has often taken place through the provision of flagship cultural facilities—such as theatres, museums, or art galleries—with the hope of triggering broader processes of urban regeneration. These flagship facilities are hosted in either new buildings designed by star architects, or refurbished heritage buildings, i.e., structures of great symbolic power at the water's edge. "Port out, city in" rationales tend to underpin these schemes as well.

In Liverpool's Albert Dock, the Maritime Museum (established in 1986) and Tate Liverpool (in 1988) led to a transformation of the area that was respectful of local maritime heritage and identity. The construction of the Museum of Liverpool (2011) supported the redevelopment of Mann Island (Fageir et al., 2021). Another prominent example is the redevelopment of Newcastle-Gateshead Quayside in the early 2000s (Bailey et al., 2004; Figure 2), through The Baltic Centre for Contemporary Art (established in 2002 in a former flour mill) and the Sage Gateshead (built-in 2004), along with the Gateshead Millennium Bridge (opened in 2001).

3.3. Event-Led

The emergence of mega-tertiary (Andrade & Costa, 2020) or Olympic (Pinto & Lopes dos Santos, 2022) waterfronts—where transformation is triggered by cultural or sporting mega-events—have arguably marked redevelopment practices in the 1990s and have been emerging ever since. Often, these processes feature rapid and extensive transformation, which is substantially state-led. These schemes display a variety of approaches in terms of port-city relationships. In some cases, such as Genoa, event-led waterfront

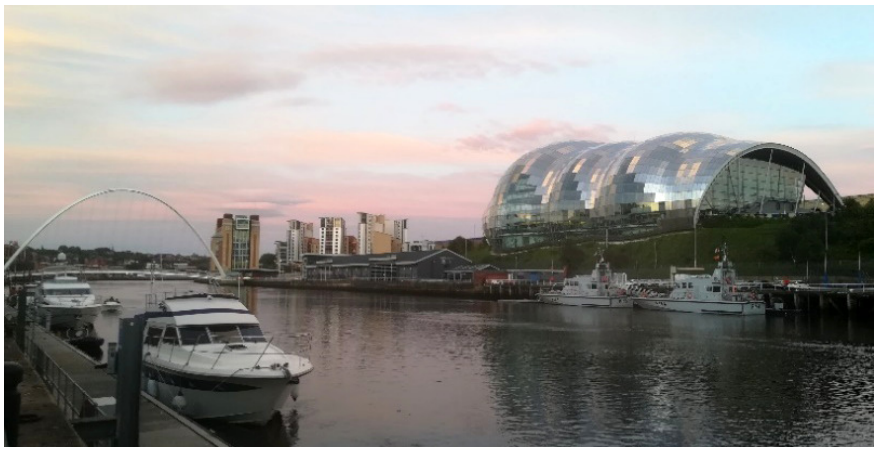

Figure 2. (Left to right) Millennium Bridge, Baltic Centre for Contemporary Art, Baltic Quay residential development, and The Glasshouse International Centre for Music (formerly Sage Gateshead) on Newcastle-Gateshead Quayside.

redevelopment was a means to transform port areas that were neither active nor of interest to the port, whilst in others, Valencia for instance, the City Council and the Port Authority worked together to ensure that new urban uses and still active port functions could coexist, for example through the physical separation of leisure and maritime traffic (Tommarchi, 2022; Figure 3).

Examples include the redevelopment of Port Vell and the construction of Port Olímpic ahead of the 1992 Olympic Games in Barcelona (T. Marshall, 2004), the regeneration of Genoa's Porto Antico in the same period to host the 1992 Columbus Expo (Z. M. Jones, 2020), the transformation of Valencia's inner harbour to host the 2007 America's Cup (Tommarchi, 2022), and Rio de Janeiro's Porto Maravilha scheme ahead of the 2016 Olympic Games (Andreatta & Herce, 2012).

One key critical aspect of event-led waterfront redevelopment is the reuse of venues and spaces post-event (see Cavalcanti et al., 2016; Tommarchi, 2023), which can substantially impact the porosity and accessibility of

Figure 3. Promenade (left) and working port area (right) on the exit channel of Valencia's inner harbour.

redeveloped waterfronts, as well as future port-city relationships. Pinto and Lopes dos Santos (2022) propose an evaluation framework to examine the failures of event-led regeneration on the waterfront by looking at five "wrongs," including the lack of attention to local specificities, inaccurate cost/benefit analyses, short-term views, poor project management, and the damaging impact or missed opportunities of poor accessibility and unnecessary use of concrete surfaces.

3.4. Late Neoliberal

There is widespread agreement among scholars that, as well summarized by Porfyriou and Sepe (2017, p. 7), waterfront redevelopment is ultimately about market-led regeneration, regardless of the approach taken. However, the first two decades of the 21st century have arguably heralded a number of implemented (or proposed, such as Liverpool Waters and Newcastle's Giants on the Quayside) waterfront redevelopment schemes designed to maximise the value that can be extracted from these areas. Although these schemes resemble tertiary-led initiatives in the 1980s as manifestations of the mobility of capital and globalising pressures, they also display distinctive features. In such cases, the design and functions, as well as the spectacularisation, of the waterfront appear to be guided by what Phelps and Miao (2020) call urban speculation, where goals of rent-seeking, along with the power of global rent-seeking elites, are dominant, leading to aggressive, semi-authoritarian policies of real estate development—see Koelemanij's (2021) idea of the "Dubaification" of waterfronts—and city branding. This approach is intimately connected with the growing financialisation of real estate (Aalbers, 2016), which has turned into an array of assets where hypermobile global capital can be channelled, and ultimately a haven where wealth can be protected (see Atkinson, 2021). Waterfronts of this kind tend to include entertainment and event venues (*stadia*, arenas, and conference centres), retail and hospitality, and display the presence of large collective spaces that are nonetheless privately owned. They can also focus on a combination of super-luxury housing and retail, sometimes creating hyper-gentrified new parts of the city that are unaffordable to the vast majority of its dwellers, or urban enclaves. It is argued here that these processes, as opposed to public-led waterfront redevelopment processes in the 1980s and 1990s, can be analysed effectively through growth machine theory (Cox, 2017), by exploring how growth coalitions push for the implementation of such schemes. These schemes arguably tend to leverage the symbolic power of proximity to water in order to target affluent consumers and foreign capital. Therefore, there is no place for "the port," intended either as an assemblage of port-related activities or as a vessel for vestiges of the city's port culture and heritage.

The business-friendly (Camerin, 2019), Florida-inspired (Muñoz, 2006) Diagonal Mar in Barcelona (Figure 4)— next to the event-led Parc del Fòrum development—is an example. Its anyplace character is in stark contrast with previous waterfront redevelopment schemes implemented in the city. Liverpool's Kings Dock is another example, where the Echo Arena and the nearby international hotels create a post-industrial, globalised urban space that erases any physical and symbolic connections with the city's historic waterfront. In addition, Liverpool Waters (P. Jones, 2015), planned to be implemented just north of the city centre, led UNESCO to strip Liverpool's historic port areas of their World Heritage Site status (West, 2022) based on the argument that the new development was going to compromise the historic value of the port cityscape. Other examples of this trend may be found in port cities in the Global South, such as the Jeddah Corniche Waterfront (Mostafa, 2017).

Figure 4. Shopping centre, hotel, and office block in Diagonal Mar (Barcelona).

Due to their design and mix of functions, these schemes present issues in terms of accessibility and "porosity" (as defined by Hein, 2021) of waterfronts, and safety outside their "working hours." In a similar vein as 1980s tertiary-led schemes, they tend to push port-related activities out, and to be homogenised, giving "the sense that if you have seen one waterfront, you have seen them all" (Stevens & Dovey, 2004, p. 364). Consequently, this homogenisation prompts issues of erosion of local maritime culture and heritage in favour of the production of standardised urban environments and a more saleable image (raised for example by Chang & Huang, 2011; Kowalewski, 2018; Richards & Wilson, 2006). In other words, processes of economic and cultural de-maritimisation (Musso & Bennacchio, 2002; Tommarchi, 2021) can be observed as a characteristic of these schemes, which tend to generate opposition from residents.

3.5. Holistic

In recent years, we have been witnessing a growing number of schemes that, despite being driven by the market, aim at a more balanced redevelopment model for urban waterfronts, by embracing the broader dimensions of sustainability and urban resilience and seeking a mix of functions including (affordable) housing, education and culture, commercial and retail, but also compatible industrial and port uses (Andrade, 2018; Bruns-Berentelg et al., 2022; Daamen & Vries, 2013). Some of these schemes respond to long-lasting critiques of "port out, city in" strategies pointing to the fact that urban and port/industrial uses could—and possibly should—coexist in port cities (Andrade, 2018; Charlier, 1992; Van Hooydonk, 2009). Similarly, some of them meet Stevens and Dovey's (2004) suggestion to apply to waterfront redevelopment Jane Jacob's remark that the development of the urban fabric should happen gradually, unsystematically and at a small scale. A relatively "fine-grained" approach encompasses a mix of functions and attempts to retain or reintroduce port-related or light industrial activities, sometimes pointing to processes of economic and cultural re-maritimisation (Musso & Bennacchio, 2002; Tommarchi, 2021).

For example, the development of HafenCity in Hamburg was envisioned as "a diverse yet physically small-scale mix of…uses, from residential to industrial" requiring "a sophisticated and well-balanced concept, with various uses mixed both vertically and horizontally: within a building, between buildings, within a quarter, and between quarters" (HafenCity, 2006, p. 55). HafenCity still displays a "port out, city in" approach (Daamen & Vries, 2013; Schubert, 2020), however, its mix of functions, quest for sustainability, and celebration of the proximity of this new part of the city to the working port also portray a different picture of what future urban waterfronts might look like. In Rotterdam, the development of the Makers District—referring to the Merwe Vierhaven and Rotterdamsche Droogdok Maatschappij areas—can be seen as a production-oriented waterfront redevelopment strategy, as opposed to the largely consumption-oriented strategies underpinning many of the cases cited in this article, that aims at bringing a range of productive activities back into the heart of the city. The redevelopment of the Merwe Vierhaven area sees a combination of manufacturing and creative functions that will coexist with other urban uses including housing, whilst the Rotterdamsche Droogdok Maatschappij campus (Figure 5) is a beacon of technological innovation, specifically in port-related activities, with both schemes effectively connecting to local maritime and water-related heritage assets and values (Jansen et al., 2021).

Figure 5. Rotterdamsche Droogdok Maatschappij campus in Rotterdam.

4. Where Are We Going? A Forward Look at Waterfront Redevelopment in the 21st Century

This article has proposed an updated typology of approaches to waterfront redevelopment, looking in particular at experiences in the last 25 years. It has shown how schemes identified here with the proposed terms "late neoliberal" or "holistic" have emerged, signalling not merely an evolution of existing approaches but the emergence of new ones. It is argued that such new approaches are set to become widespread in the immediate future. On the one hand, late neoliberal waterfront redevelopment schemes are expected to become more frequent, signalling a spatial manifestation of the growing power and mobility of global capital, and the greater pressure that powerful global players are able to exert locally. In an increasingly interconnected and uncertain economy, investment in real estate development is arguably likely to become more prominent as a "safer" option. On the other hand, holistic approaches to waterfront redevelopment are

also expected to become more widespread as a means to address climate change adaptation in coastal or riverside port cities (through coastal defence and water management infrastructure, mitigation of urban heat island effects, and carbon sequestration), and to pursue sustainable development more broadly in areas such as liveability, wellbeing, cultural opportunities, and inclusion. However, late neoliberal and holistic approaches display opposite strategies as regards their planning and the model of port-city relationships they promote, in a context of rapid economic and societal change, as well as of changing ties between ports and cities.

As noted in the mid-2000s by Sairinen and Kumpulainen (2006, p. 122), waterfront redevelopment "needs to be planned more cautiously" than in the past. Arguably, their interpretation is even more valid in today's uncertain and crisis-prone world. Today, waterfront redevelopment strategies seem to be more dependent for their success on engaging with local meanings (Tommarchi & Jonas, 2024), which appeared to be less central to the—at least perceived—success of past practices (e.g., tertiary-led schemes in the 1980s). Positive forms of re-maritimisation where cities are reconnected with the sea and their port city culture (such as in the case of Genoa), the restoration and rediscovery of local history and heritage, greater accessibility, and better quality of urban spaces are more likely to be voiced as needs and expectations amongst port city dwellers. This becomes pivotal when considering the standardisation of urban environments (Stevens & Dovey, 2004) and the heightened socio-spatial inequalities and symbolic separation between the waterfront and the city (Porfyriou & Sepe, 2017) fostered by many of the previous examples mentioned. As a result, late neoliberal approaches are likely to generate more opposition and, ultimately, conflict, which may lead to the failure of these schemes. Studies exploring the politics behind regeneration show how the coalitions that develop around such schemes can deploy several tactics to build acceptance or stifle opposition (e.g., Kallin & Slater, 2014; MacLeod, 2011; Tarazona Vento, 2017). Further research is needed to explore this tension, for example in terms of changing governance processes behind waterfront redevelopment, growing socio-economic and spatial inequalities exacerbated by such practices, and the rise of forms of authoritarian capitalism.

On the other hand, changing port-city relationships are questioning the established "port out, city in" rationale behind waterfront redevelopment practices in the 20th century (Wiegmans & Louw, 2011), as well as the very nature of future urban waterfronts. Waterfront redevelopment has often been about replacing port/industrial functions with tertiary functions or spaces for consumption. We are witnessing a renewed interest from certain port-related or industrial activities (e.g., in the areas of logistics, renewable energy, recycling, and green manufacturing) to locate on urban waterfronts, which is welcome by port city governments as a means to pursue economic revitalisation and create jobs locally. More "holistic" approaches to the design of the 20th-century waterfront city (e.g., HafenCity and Makers District, and in particular where port-related activities are re-introduced) seem to address the current need for more economically and socially sustainable waterfronts that do not rely solely on consumption patterns and therefore are more resilient to abrupt economic fluctuations. Port land ownership regimes are arguably becoming even more relevant in a context of increasing deterritorialisation of ports (Daamen & Vries, 2013; Tommarchi, 2022) and a growing community of actors on the waterfront that are involved in global investment in real estate. Further research is needed to explore this growing governance complexity and the risks that physical fragmentation arising from complex ownership regimes undermines the efforts of planning new urban waterfronts at a more sustainable, fine-grained scale.

Holistic schemes such as the Porto Vivo (meaning "living port") initiative in Trieste are emerging as bold initiatives to promote sustainable ideas and practices. Porto Vivo aims to transform a large section of the

historic harbour into a new urban waterfront area hosting hi-tech and creative industries, a sustainable transport network, and a large green area. Although large parks and areas at the port-city interface playing important ecological functions have been part of port-city planning agreements in the last decade (e.g., Valencia's Parque de Desembocadura), this approach seems to be fundamentally different from the strategies guiding the (internationally acclaimed successful) redevelopment of similar historic harbours in the past decades (e.g., Genoa and Barcelona). Research is needed to explore the implications of such a change in the fundamental ideas of what urban waterfronts are and can become. The shift is from a widespread notion of redeveloped waterfronts as inherently connected to leisure, to an understanding of waterfronts as dynamic parts of a port city where port and compatible industrial activities blend with creative businesses, affordable housing, and green infrastructure. Can this become a model for more sustainable urban waterfronts across port cities?

Finally, fundamental questions for future research on waterfront redevelopment are raised by the upcoming transition of ports to a post-oil economy (Hein, 2018), and the consequent profound restructuring of ports worldwide (Daamen & Vries, 2013). This is especially the case of the feasibility—and possibly the desirability—of the reuse and transformation of a range of urban port areas, both in terms of resources but also of planning concepts and sustainability concerns. Ultimately, as suggested by Dovey (2005) in relation to 20th-century schemes, the redevelopment of urban waterfronts will continue to be a major opportunity for experimenting with new concepts and practices of urban design, planning and governance.

Funding

Part of the research behind this article was funded by the University of Hull through the bursary Culture-Led Urban Development and Regeneration_01.

Conflict of Interests

The author declares no conflict of interests.

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Ocean and Society
2025 • Volume 2 • Article 9285
https://doi.org/10.17645/oas.9285

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Open Access Journal

Investigating Port Spatiality: Tools for a Spatial Approach to Port Clusters

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Submitted: 14 September 2024 **Accepted:** 16 December 2024 **Published:** 26 February 2025

Issue: This article is part of the issue "Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions" edited by Mina Akhavan (TU Delft), Yvonne van Mil (TU Delft), and Carola Hein (TU Delft), fully open access at https://doi.org/10.17645/oas.i442

Abstract

Today, half of European port managing bodies administer two or more ports. Contemporary port-city territories are increasingly shaped by processes of "spatial clustering," which call for a reassessment of the tools used to investigate and design these areas. Port clusterization refers to the administrative aggregation of two or more ports into clusters, a phenomenon that has the potential to affect port spatiality by defining a new spatial typology of ports, characterized by polycentricity and territorial extension. Despite the absence of established theories and tools for analysing such extended spaces, the rise of port clusters is giving way to new governance models for optimizing coastal areas and specializing land–sea infrastructures. This article, part of the EU-funded PULSE (The Port-clUster LandScapE) project, examines the impacts of port clusterization by introducing the concept of "port-cluster landscapes"—whose investigation contributes to developing a spatial and design-based approach to ports. In this context, the port-cluster landscape emerges as a spatial typology of interconnected ports and overlapping flow systems. Methodologically, the article outlines the tools formulated to study two Italian port clusters, including multi-level maps and the Indicator System, a set of 12 spatial indicators conceived within the framework of the project and being applied to these cases. Ultimately, the article explores port spatiality, highlighting the need for new regional collaborations and spatial reconceptualization, which can be fostered through transformative design projects in the context of port clusterization.

Keywords

multi-level maps; port city territory; port cluster; port spatiality; spatial engagement; spatial stretching; technical lands

1. Introduction

1.1. Theoretical Framework

Today, half of European port managing bodies administer two or more ports (European Sea Ports Organisation [ESPO], 2022). According to the ESPO's report *Trends in EU Port Governance*, more and more ports are clustering, either with other ports, or with other stakeholders in the port ecosystem and beyond.

Port clusterization, which involves the administrative merging of two or more ports within the same region, is driving "spatial clustering" processes in contemporary port-city areas. This, in turn, is giving rise to new spatial categories. Deciphering these emerging categories calls for a multidisciplinary approach, mirroring the complexity of the cluster concept in and of itself (Moretti, 2023).

According to Notteboom et al. (2022), "ports clusters consist of geographically concentrated and mutually related business units centred around transport, logistics, trade, and industrial production." It is interesting to note, from the point of view of "spatial engagement," how, in their extensive study on the subject, the authors identify important geographical attributes behind port cluster formation, which varies substantially by maritime range, mainly owing to a set of constraints such as availability of port sites (coastal geography and distribution of cities), administrative divisions, hinterland accessibility and density, economies of scale, and infrastructure.

The emergence of port clusters in the European framework aims not only at restructuring port governance, but also at generating new administrative patterns and strategic models to optimize coastal spaces and specialize land–sea infrastructures between the ports of the same cluster. Many of today's challenges, such as geopolitical changes or tensions, energy transition, the increase in scale and integration of the maritime sector, or technological complexity, may be beyond the possibilities of a single port management body. Additionally, the scarcity of available port land on the other hand expands the possibilities for port cooperation (ESPO, 2022).

Port clusterization is heavily impacting the institutional sphere of ports; however, in this process, not only does this phenomenon have no control over cities, but its spatial component is being overlooked. Recent contributions have denoted that key issues related to spatial dynamics in port clusters remain unexplored (Ducruet & Notteboom, 2020; Moretti, 2023; Pavia, 2016). Even in a broader outlook, according to geographer Vorley (2008), while the concept of the cluster is largely used to describe agglomerations, interconnected networks, and concentrations of firms, its spatiality is less clear. Intended as an evolution of the "port regionalization" phenomenon (Notteboom & Rodrigue, 2005), port clusterization has the potential to radically transform areas that are becoming increasingly extensive and complex. It doesn't concern only a supplanting of administrative borders, but an intense "spatial stretching": a physical expansion of coastal and marine areas that, through these developments, evolve into interconnected, multidimensional spaces. This stretching generates new spatial patterns of functional relationships for port–city–territory interfaces (Robinson, 1968), including the infrastructure and architecture systems that serve as both barriers and connectors between land and sea.

With this approach, port clusterization does, in fact, affect space. It defines an unprecedented typology of ports which embodies the principles of physical proximity and functional complementarity that several port cities have been pursuing for decades, aiming to replace the obsolete idea of competition between neighbouring ports. The concept of cluster sharply introduces the networked dimension of contemporary territories: a dimension that goes beyond the investigation of individual polarities and replaces them with polycentric visions.

1.2. Main Argument

The main argument of this contribution lies in advocating for the investigation of the spatial products of port clusterization—which the study calls port-cluster landscapes—with spatial design tools. The port-cluster landscape is introduced as a form of port spatiality consisting of multiple ports and overlapping global and local flow systems that, together, produce an unexplored spatial figure within the built environment. As an overarching goal, the contribution questions how, at the introduction of port clusterization, it is imperative to formulate tools that encourage new regional collaboration and spatial reconceptualization.

The study is carried out in strategic contexts in Italy where the merging of ports is relatively recent and allows an observation of the unfolding process. The identification of spatial indicators and multi-level mapping, as the article will deepen, are the key tools to develop spatial knowledge and design practice for architects, planners, and governing bodies to contribute to the understanding of port clusters.

Numerous studies dealing with urban-port spatial conditions have defined the nature of the port–city relationship by mainly focusing on the characters of the interface between the two entities. Renowned are the contributions of maritime geography in this field, among them Brian Hoyle for whom the port–city interface may be described as a system, or as a concept, or as a series of mechanisms that link port and city (Hoyle, 2006). The work of Hayuth (1982) was among the first to introduce the idea of the port–urban interface area as a zone in transition. His research reflects on the land-use characteristics of the urban waterfront in the new era of ocean transportation when, at the end of the 20th century, the coexistence between city and port became conflictual and spatial segregation increased.

More recently, other theories introduce the regional dimension that transforms ports into large-scale exchange nodes (e.g., the aforementioned port regionalization) and the economic component that drives the formation of port clusters. Following these studies, we witness a process of clustering of ports that, on the one hand, concerns the ”clustering of ports around a maritime range,” and, on the other hand, encompasses the “clustering of activities around a port” (Notteboom et al., 2022). Both processes do not appear to provide a comprehensive image of the spatiality of the cluster, of what its formal and settlement characteristics are, or what its spatial repercussions are on contemporary urban-port features.

In this evolving framework, it is believed that the concept of port-cluster landscape can challenge existing contributions and extend the field of studies on urban-port spatial conditions. Exploring the impacts of port clusters on space will push research beyond its current boundaries by addressing a crucial yet underexplored phenomenon. If the idea of the city–port interface, although groundbreaking at the end of the last century, today refers to a dimension that is conceptually distant from the systemic approach of contemporary ports, the port-cluster landscape refers, instead, to a new polycentric feature.

Believing that the formalisation of port clusters can generate a landscape of its own, able to surpass the idea of individual cities, contributes to understanding new networked built forms that have recently been emerging, as results of broader processes of global urbanization. The concept of port-cluster landscape deals with the spatial qualities of active urban-port territories, complementing the definition of port clusters traditionally employed in maritime economics. Not only "clusters of companies and economic activities" (Notteboom et al., 2022), but also "new types of landscape" produced by institutional transformations. Here the use of the term "landscape" is key because it refers to landscape urbanism theory, with which Charles Waldheim highlighted the process of semantic emphasis that, since the late 20th century, enriched the notion of "landscape(s)" (Waldheim, 2016). If it was conceivable to rethink the city through landscape, why not rethink the port through it too?

As part of the ongoing EU-funded research PULSE—The Port-clUster LandScapE: Developing a Spatial and Design Approach to Port Clusters (see Acknowledgments), this article introduces the set of tools built to study the spatial impacts of port clustering in two Italian port contexts.

1.3. Structure of the Article

Section 1 includes the theoretical framework of the contribution framed in relevant bibliographical references and previous publications by the author. The main argument is outlined by specifying the potentiality to study the spatial footprint of port clusters, and by detailing the research's funding context.

Section 2 opens by establishing theoretical-lexical assumptions about the terms used in the research. The terms here shown—"cluster," "system," "region," and "port city territory"—are employed to define regions of meaning.

Section 3 delves into the phenomenon of port clusterization in Europe, presenting it as an evolving scenario. It illustrates the methodological structure of the study, highlighting its general approach, research phases, and their corresponding Work Packages (WPs). The section also shows the toolkit as the final result of the study.

Section 4 presents the Indicator System and the mapping activity. To do so, it provides a description of the 12 spatial indicators, as well as a first version of the multi-level maps featuring the Port Network Authority of the Eastern Adriatic Sea (Ports of Trieste and Monfalcone).

Section 5 addresses port spatiality in its polycentric and polymorphic nature. Concluding with an open debate, the article shows how the concept of port-cluster landscape can be applied in the fields of architecture and design of port cities, and it also presents first design recommendations and routes that will be taken to ensure the exploitation of research results.

2. A Glossary of Port Spatiality

The terminology we use in scientific reasoning mirrors the fields of research in which we claim to position our work. A study that centralizes the process of port clusterization and the notion of cluster, hence, questions neighbouring terms with the intention of delineating the focus of its reasoning. Besides, the more the concept of cluster is interdisciplinary, the more meaningful is the search for a common language.

Specifically, the glossary developed in this study features 12 terms: "cluster," "comprehensive & core port," "hinterland," "logistics zone," "network," "port catchment area," "port cityscape," "port city territory," "range," "region," "seaspace," and "system."

As a main goal, connections were sought between the 12 terms and the notion of space. Namely, it was examined whether and how the terms had implications and declinations related to the spatiality of territories. The glossary questions whether there is a spatial embedding, and/or a spatial engagement of these terms and how this may influence urban design and architecture.

To give a sample, some terms from the glossary—i.e., "region," "port city territory," "system," and "cluster"—are reintroduced below. They provide a theoretical-lexical basis for the article and motivate the use, in the study, of the term "cluster" instead of "system," and the formula "port city territory" instead of port city "region."

In a more unified reading of the four terms, we can critically examine them through two binomials ("cluster"/"system" and "region"/"port city territory") that do not necessarily put them in contrast but interpret them through a comprehensive and integrated approach. If the notion of "system" refers to a mechanical dimension that indicates (and requires) physical proximity between the constituent parts, that of "cluster" is instead a broader construct, conceptually and physically. Transcending administrative and political boundaries and the geographical closeness of the system poles, it concerns the set of tangible and intangible relations that develop between ports and port-related activities on land as well as on sea, realizing the stretching process already mentioned. Focusing instead on the "region"/"port city territory" binomial of terms, it is considered that the notion of "port city territory" is not only more all-encompassing than that of "region" in order to develop a study on port clusters, but is able to capture the territorial heterogeneities and the spatial footprint that mark clusters' form and structure. "Port city territory" is a term that is capable of considering the terrestrial hinterland as well as the maritime hinterland of a port city, thus generating a third type of space that, indeed, demands new definitions. The term "region," on the other hand, keeps a descriptive nature and, consequently, lacks operational explanatory power. Although this term, thus understood, encompasses the network of logistical corridors gravitating around a port, it often has some correspondence with administrative and legal boundaries, making reasoning less flexible.

2.1. Cluster/System

First defined by the Belgian scholar Haezendonck, the port cluster is described as follows:

> The set of interdependent firms engaged in port related activities, located within the same port region and possibly with similar strategies leading to competitive advantage and characterized by a joint competitive position vis-à-vis the environment external to the cluster. (Haezendonck, 2001)

The cluster is a "driver." It fosters the competitiveness of industries, increases the productivity and efficiency of clustered locations, stimulates and enables innovation, and facilitates commercialization, knowledge exchange, and the formation of new entrepreneurial activities.

However, the cluster is also capable of identifying and generating a physical area of application and influence: Within it, ports, major and minor, work as territorial centralities and hinges at the scale of the city

and individual architectural elements. Other poles—including logistic platforms, inland ports, infrastructural exchange hubs, and, in particular, cities linked to these ports—contribute to the production of a complex and constantly evolving relational framework. Based on the work of de Langen (2004), Kocsis recognizes the existence of a port region because "port activities are shared among many municipalities and concentrated not only in port cities. Many times in port cities fewer port activities are found than in cities close to the actual ports" (Kocsis, 2011, p. 53). Understood in this way, the notion of port region complements and supports the idea that the cluster has a physical and spatial impact on territories.

With the aim of affirming renewed attention to the role of space as a strategic tool, the formalization of port clusters introduces the mechanism of "spatial clustering" in the operational territories between land and sea. It also highlights the latent potential of in-between territories that connect ports, motivating the study of the port-cluster landscape, i.e., the spatial product of the port clusterization phenomenon. The notion of port-cluster landscape is better understandable if linked to that of port cityscape, theorized by Hein in her work (2019). According to this definition, space plays a crucial role:

> Many contemporary ports are surrounded by high fences and are controlled by special institutions, but their spatial footprint—for example through infrastructure, warehousing, and logistics networks—as well as their environmental impact—for example, air, water, soil or noise pollution—extends far beyond the port's demarcated borders into neighbouring cities and regions. The result is a port cityscape, a networked space that extends from land to sea, including ships and pipelines, port facilities and warehouses, industrial and logistic structures, headquarters and retail buildings, but also housing and leisure facilities. This port cityscape is administrated, planned, imagined and represented by multiple institutions and rarely as part of a shared vision. (Hein, 2019., p. 4)

According to Notteboom et al. (2022), a port system can be defined as "a system of two or more ports, located in proximity within a given area." In the literature, various geographical and functional scales have been identified ranging from complete coastlines (e.g., the west coast of North America as one port system) to the notion of a "range" (Vigarié, 1964) and a "multi-port gateway region" (Ducruet, 2009). When one approaches the study of port systems in maritime network analysis, one is confronted with studies that had in common that they considered port development from a strict land-based perspective. This was criticized during the same period by Rimmer (1967), who called for the inclusion of maritime linkages in the study of port systems (Ducruet & Notteboom, 2020).

Other studies by Ducruet and Notteboom (2020) have observed that the definition—and consequently the boundaries—of port systems differ significantly across the academic sphere, often being conflated with concepts such as a coastline, a nation, a region, or a broader maritime area, encompassing seas, basins, or even entire port networks. Additionally, port system analysis has historically focused on small clusters of ports within national borders, reflecting the assumption that port systems are primarily shaped by geographic proximity and political boundaries.

These reflections are aligned with certain guidelines recently issued in national contexts, i.e., Italy, where the clusterization phenomenon is becoming more and more consolidated. The 2017 *Linee Guida per la Redazione dei Piani Regolatori di Sistema Portuale* (Guidelines for the Drafting of the Port System Regulatory Plans) were drawn up to manage these new port systems. They deal with logistics and infrastructure connections but

above all reflect on a new definition of "port." A definition that recognizes that the scope of port planning may not coincide with the territorial jurisdiction of the Port System Authority (PSA). In some cases, maritime areas owned by the state may fall outside this jurisdiction if deemed non-strategic for port operations. Conversely, some non-state-owned areas may be included, since they are functionally linked to the port.

2.2. Region/Port City Territory

Research by Notteboom and Rodrigue (2005) seeks to contribute to the existing literature by introducing a phase of port regionalization in the evolution of port systems. They stated:

> The phase of port regionalization not only expands the *Anyport* model of James Bird (1963). It also extends the existing literature on the spatial development of seaport systems in relation to maritime and hinterland networks. The geographical system would evolve from an initial pattern of scattered, poorly connected ports along the coastline to a main network consisting of corridors between gateway ports and major hinterland centres. (Notteboom & Rodrigue, 2005, p. 3)

Overall, looking into the extensive bibliography about port clusters mainly in economic geography, the port region seems to be a rather descriptive term, lacking clear substance or operational explanatory value. As a result, geographer Ducruet (2009) affirms that the port region remains a multifaceted concept embracing different realities such as the economic area around a port (i.e., the port region *stricto sensu*), the logistics area connecting the port (i.e., the hinterland), and the area in which inter-port relations take place (i.e., façade, range, or system of ports).

Shifting the reasoning to the notion of the port city territory, Hein et al. (2023, p. 22) describe it as "a distinctive type of space that includes a maritime foreland and a terrestrial hinterland, a space where ports have major impact on and co-exist with urban settlements and rural areas." In their 2023 *Port City Atlas*, which collects 100 maps of port city territories elaborated to serve as foundation for future research and policymaking, the authors point out the reasons for using the term "territory" rather than the term "region" in association with the binomial "port city":

> The port city territory as a whole is not an institutional or statistical entity. On the contrary, it crosses institutional and administrative borders, and is often difficult to recognize due to absence of clear spatial borders and relevant datasets. (To distinguish this concept from administrative language, we opted to not use the term region, as in port city region). (Hein et al., 2023, p. 24)

3. Port Clusterization in Europe

3.1. An Evolving Scenario

Port clusterization involves the administrative consolidation of two or more ports, which may not be located within the same region or country but operate within a shared economic, political, and infrastructural context. Driven by financial and logistical advantages, this model has been implemented in various European settings since the late 20th century. Notable examples include the Copenhagen–Malmö cluster, which has been managed by a single port authority in the Baltic region since 2000, and the 2021 partnership between Paris,

Rouen, and Le Havre (HAROPA Port), a key river and seaport axis that provides Atlantic access to activities along the Seine River. In both instances, the establishment of this new governance framework has set the stage for spatial changes that will unfold over several decades. Other interesting cases can be found in this perspective: the Port of Antwerp-Bruges (Belgium), a limited liability company of public law with the City of Antwerp and the City of Bruges as shareholders, formalized in 2022; the Valenciaport that, since 1992, includes the three state-owned ports of Valencia, Sagunto, and Gandìa; and the APBA—Port of Algeciras Bay Authority (ports of Algeciras Bay and Tarifa), which, since the 1990s, is a public organization that belongs to the Ministry of Transport, Mobility and Urban Agenda. Moving outside Europe, the phenomenon concerns, e.g., the area of New South Wales in Australia: The Port Authority of New South Wales is in fact a company owned by the government that acts as harbourmaster in the state's six commercial ports.

In Italy, the concept of port systems was already included in the first port law enacted in 1994. Law No. 84/1994 recognized the port as a system with the potential to impact areas beyond the state-owned land directly connected to maritime traffic. However, it was not until the 2016 Port Reform that the 24 Port Authorities were consolidated into 16 PSAs under Legislative Decree No. 169. Port clusterization in Italy has been also coordinated with the formalization of metropolitan areas in 2014 which eliminated the figure of provinces by merging more cities and territories (Law No. 56/2014). Although the consequences of the two laws are not yet tangible, it is clear that they contribute to introducing new scenarios not only for ports, but also (or above all) for cities involved in these changes.

Governance and planning are intricately linked, particularly at the intersection of city and port. Government structures shape the planning efforts of both public and private entities involved in transforming spaces located at the port–city boundary, where the impact of planning tools is generally less clear (Moretti, 2020). However, the coordination brought about by the clustered model has yet to produce immediate changes in the planning strategies employed by ports. While some clustered ports are exploring ways to organize their activities more effectively and complementarily, in other regions (particularly in Italy), PSAs remain independent, and focused on local projects. Extending this argument, administrative consolidation creates a new dynamic that stretches along the coast and into the hinterland.

3.2. A Spatial Methodology for Designing Port Clusters

The main spatial impacts related to the phenomenon of port clustering are studied employing a space-based methodology articulated in three main research phases, namely "Investigation," "Crossing," and "Formulation." The methodological structure is also displayed in a diagram illustrating the research phases and detailing their activities, tools and results (Figure 1). The results of each phase constitute a "toolkit" of lexical categories (Glossary), maps (Atlas), and strategies (Catalogue) to contribute to the design of contemporary port clusters.

A founding principle lies in the analytical combination between the scientific knowledge brought by academic research and the operational knowledge guaranteed by the active involvement of public institutions, both in Italy and beyond, and international associations capable of strengthening dialogue. As shown in the methodology illustrated in Figure 1, co-design and co-creation activities (workshops, online sessions, seminars, etc.) were used as tools to advance research. The implementation of these activities has been carried out thanks to the support of the network of Italian PSAs—the Association of Italian Ports (Assoporti)—and the Worldwide Network of Port Cities (AIVP).

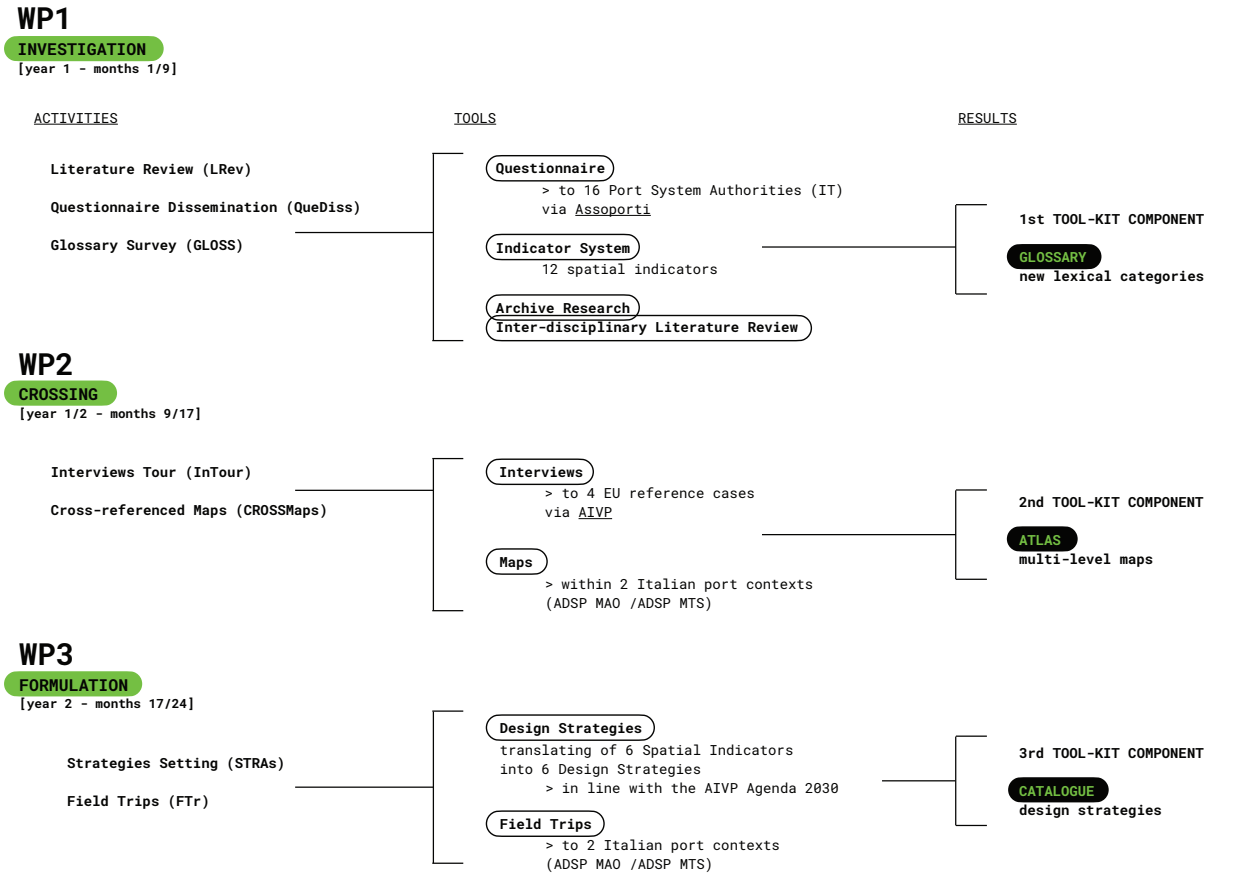

Figure 1. Diagram of research methodology. Note: Figure concept and graphic elaboration by Beatrice Moretti.

Through the setting and sharing of a questionnaire and a collaboration with the 16 Italian port systems that represent an early stage of clusterization, the "Investigation" phase records the spatial impacts emerging from the Italian context. As a result, it builds the Indicator System, an evaluation tool consisting of 12 spatial indicators referred to the port cluster dimension. The construction of the Indicator System as a methodological tool comes both from data collected through the literature review and from the discussion triggered with the 16 Italian port systems through the questionnaire. Studying the literature related to the concept of clusters (especially in the geographical field), certain definitions were used in order to decline them in a port spatial context: e.g., the definition by Swann and Prevezer, "clusters are here defined as groups of firms within one industry based in one geographical area" (1996), or Rosenfeld's definition according to which "a cluster is very simply used to represent concentrations of firms that are able to produce synergy because of their geographical proximity and interdependence, even though their scale of employment may not be pronounced or prominent" (1997). Concepts such as rationalization, inclusiveness, proximity, complementarity, coordination, and concentration were involved to originate the 12 indicators. Further validation of the indicators came via the questionnaire, in the form of co-design and co-creation activities, and allowed for the final tuning. In some cases, the responses resulted in additions of new indicators. For example, when answering the question of what were the main spatial impacts brought in by the port clusterization phenomenon, one of the respondents suggested that clustering has led to the modification of the port skyline and landscape through the updating of the former edges of the sea–land interface due to the new clusterization scenario. This contribution gave rise to the definition of indicator 11 "Visual modification of the port skyline—VisModPortSky." An additional co-creation exchange was

instrumental in the definition of indicator 9 "Perception/acceptability of the port from/by the port-city territory—PercAcceptPortCTerr": the concept of perception initially proposed was expanded to the notion of acceptability, to include the role of urban-port communities (WP1 "Investigation").

The Indicator System is employed as a cross-reference tool in the "Crossing" phase to study the spatial impacts of the port clusterization phenomenon and, according to it, draft multi-level maps able to represent the port cluster's spatial dimension within two selected Italian port city territories where an early stage of clusterization is noted. The Indicator System is also employed to deepen, through a set of interviews, the clustering status of four international port clusters in which it is possible to detect an advanced stage of clusterization. The two Italian port city territories selected for the mapping are the Port Network Authority of the Eastern Adriatic Sea (Ports of Trieste and Monfalcone) and the Port Network Authority of the North Tyrrhenian Sea (Ports of Livorno, Piombino, Capraia, Portoferraio, and Rio Marina). The four international port clusters are the HAROPA Port in France, the North Sea Port between Belgium and the Netherlands, the Valenciaport, and the APBA—Port of Algeciras Bay Authority, which manages the ports of Algeciras Bay and Tarifa, both in Spain. These selections—both of advanced and preliminary cases—are made based on notions deduced from the previous research phases and collaborations with experts, such as AIVP, which facilitated fruitful exchanges. The mapping activity was carried out through co-design and co-creation sessions with experts (architects, engineers, planners, and GIS specialists) belonging to the two selected PSAs in Italy. As for the questionnaire, the wealth of knowledge and data they provided is an indispensable starting point for building reliable research instruments (WP2 "Crossing").

In the "Formulation" phase, the spatial impacts already studied and visualized in the maps are translated to develop design strategies. Specifically, 6 of the 12 indicators are further examined according to a logic of higher occurrence, intensity, and frequency of their impact on the territories of the two Italian selected cases. The resulting design strategies aim to be in line with the 10 goals of the AIVP *Agenda 2030* (AIVP, 2018), which were adapted from the UN's 17 Sustainable Development Goals for the specific context of city–port relations. Contemporary port clusters need to be confronted with the global framework of guidelines and standards already in place to guide their development and projects in specific places. So, the connection pursued with the AIVP *Agenda 2030* is motivated by the aim of validating the research results with current policies in terms of the management and design of urban-port spatial conditions and to facilitate their future exploitation through the drafting of a policy brief (WP3 "Formulation").

4. Displaying Spatial Impacts Through Multi-level Maps

4.1. Twelve Spatial Indicators

The increased cooperation of neighbouring ports was already a growing trend between 2010 and 2016, which happened either bottom-up, because of cooperation between port managing bodies, or driven by government policy (ESPO, 2022). As recent mergers, the 2022 ESPO report acknowledges the North Sea Port (Ghent, Vlissingen, Terneuzen) unified in 2018, the HAROPA Port (Le Havre, Rouen, Paris) in 2021, and the Port of Antwerp-Bruges (Antwerp, Zeebrugge) in 2022. This list includes also Italy where, since 2016, old port authorities have been replaced with new PSAs to which several ports belong. As a result, the consolidation of port authorities has brought together 62 Italian ports, decreasing the number of governing bodies from 24 to 16.

However, there are differences between the above cases. While in the HAROPA Port case the three ports forming the cluster had already been operating in a merger and complementary logic for decades, in Italy the unification of ports was introduced by central government bodies, with a top-down approach. They are recently established port systems that, for research purposes, are considered an expression of an early stage of clusterization. In fact, as Hein et al. (2023) maintain:

> [In Italy] the central government decides on finances, while the PSAs coordinate and plan ports logistics and expansion. Changing the governance system also changed the port city territory, because the reform addressed inefficiencies related to hinterland connections. The 16 PSAs assumed the duties and powers of traditional port authorities, but with a broader geographic scope. (Hein et al., 2023, p. 65)

The mapping activity provides for data collection and elaboration of conceptual maps, generating the Atlas of Maps of the Port-Cluster Landscape. Through the application of the Indicator System, its goal is to visualize the spatial impacts within specific port contexts and to evaluate its purpose from a strategic perspective. Designed as an "evaluation tool," the Indicator System consists of 12 indicators. Shown in Figure 2, they are as follows:

1. "Degree of sea-land connectivity & geographical links—DegConGeoLks": level and intensity of physical connections involving areas and artefacts located on the coastal edge between land and sea, including the presence of natural grafts (rivers, canals, basins, etc.) capable of increasing this connectivity.
2. "Infrastructure sharing & rationalization—InfrSharRat": level and intensity of subdivision and specialization in the operational territories of the different infrastructure systems, on land and at sea, related to the port sector.
3. "Services pooling & optimization—ServPoolOpt": level and intensity of physical pooling of port services and facilities within the poles and the territories of influence of the cluster.
4. "Functional synergies and operational linkages—FunctSynOperLkg": presence, level, and intensity of operational interactions between the cluster poles at functional level, e.g., spatial synergies or overlaps between areas with similar uses.
5. "Spatial occupation of the coast—SpatOccCoast": level and intensity of physical settlement of coastal spaces.
6. "Proximity, inclusiveness, concentration of firms/industries—ProxInclConInd": level and intensity of cooperation and physical concentration of and between companies carrying out port-related activities.
7. "Coordinated planning & project tools between ports in the cluster—CoordPlanProJTools": existence and effective application of territorial governance tools at the cluster scale, i.e., plan and project tools capable of collectively involving all ports and territories within the single cluster.
8. "Port-to-city & land-to-sea overlapping—PortCityLandSeaOverl": existence and level of physical overlaps involving systems and/or services connected to both the port and the city, i.e., spatial systems simultaneously and contextually serving both fronts through the land–sea interface.
9. "Perception/acceptability of the port from/by the port-city territory—PercAcceptPortCTerr": level and intensity of reception of port infrastructure and operational equipment by the communities of the port cities that make up the cluster, also with a view to the regional scale.
10. "Port-city-territory-interfaces heterogeneity—PortCTerrInterfHet": level and intensity of functional and spatial variety between systems and artefacts located along the operational boundaries between port, city, and territory, i.e., constitutive differentiation of the interfaces.

Figure 2. The Indicator System: 12 Spatial Indicators. Note: Figure concept and graphic elaboration by Beatrice Moretti.

11. "Visual modification of the port skyline—VisModPortSky": level and intensity of the transformations that have occurred to the port landscape following the formalization of the cluster, with reference to visual changes concerning the profile and image of ports from the sea.
12. "Dual-function architectures—DualFuncArch": existence of architectural artefacts housing hybrid operational and civic functions, i.e., buildings with a dual typology and formal character.

The spatial indicators cover a wide range of aspects associated with port clusters and related operational spaces. The main aspects addressed are the morphological conformation, the infrastructural apparatus, and the incidence of port services of the sites, as well as aspects of rationalization, optimization, and sharing of resources and equipment between the ports of the cluster.

They deal with planning and project aspects by questioning to what extent and how the cluster ports develop coordinated transformation tools. Aspects of perception and visibility of the port from the urban-port territory are also assessed.

With a shift in scale, some of the indicators investigate the degree to which the port's skyline has changed following the introduction of the cluster and the presence of dual-function architectures, products of the heterogeneity and the complexity of the city–port interface.

4.2. Building an Incomplete Atlas

The "spatial stretching" affecting contemporary ports underscores not only the limitations of current governance and design frameworks but also the lack of visual representations that simultaneously capture these territories. The clusterization of ports demonstrates the rise of a broad phenomenology of new spaces (Moretti, 2023) that current interpretations only partially reproduce and which cannot be presumed to be the exclusive product of a few local specificities, as often observed in the literature on port cities.

Therefore, the Atlas of Maps of the Port-Cluster Landscape has been elaborated to apply and visualize the spatial impacts, defined in the Indicator System, in concrete contexts and evaluate their purpose from a strategic perspective. Drawn up at different scales according to the specificities of each port cluster but referring to the same levels of analysis (the "Cluster Level" and the "Port City Territory Level"), the multi-level maps assume and display the spatial impacts to be as credible as possible.

As for the questionnaire, the mapping activities were set up through co-design and co-creation sessions with experts belonging to the two selected PSAs in Italy. During the sessions, a draft of the map was shared to be used as a basis for discussion, each indicator was evaluated, and its impact was located on the cartography; to draft it more accurately, data and tables from the *Documento di Programmazione Strategica di Sistema* (DPSS) and from the official GIS platforms of the PSAs were used, where available. After a graphic post-production, the maps were shared again with the PSAs for further evaluation.

The choice of a map that descends from a collaborative path is closely related to the type of map itself. Referring to the work of Wall, space "is always under construction" and, consequently, cannot be represented with "traditional top-down architectural techniques in which designs and representations attempt to fix time and complete space" (2017, p. 110). Thus, the idea of constructing "incomplete maps," as

Wall suggests, aspires to generate tools that are open-ended to change, namely visuals to explore the evolving landscapes of the cluster.

According to this, the maps shown in Figures 3, 4, and 5 possess a conceptual slant and synthesize two notions of narrative. They read the port-cluster landscape through the filter of the 12 indicators to detect the presence, recurrence, and positioning of spatial impacts; this narrative is structured by the main author of the map. At the same time, they review the port-cluster landscape through the exchanges conducted with experts from the PSAs involved; in this process, the maps become collective and co-authored.

Far from geospatial mapping, this approach emphasizes how such maps result from a creative process of assembling, analysing, reworking, representing, and, ultimately, designing future landscapes. Built in a collaborative dialogue between academic researchers and policymakers, these maps are indetermined: they have inclusive potential and serve as "projective devices" (Wall, 2017, p. 114).

4.3. Mapping the Trieste and Monfalcone Port Cluster: A Preview

The Atlas of Maps of the Port-Cluster Landscape is articulated in seven maps encompassing the entire port system territory. To facilitate visualization, each indicator is assigned a specific key colour and/or pattern visible in the map legend. Each indicator is assigned a short acronym that corresponds to the legend, as shown in Figure 2. To provide an example, the article presents the three maps of the ports of Trieste and Monfalcone displayed at the Cluster Level (Figure 3) and at the Port City Territory Level (Figures 4 and 5). The framing of each map considers the methodological approach of the *Port City Atlas* of Hein et al. (2023), while basing it on the official perimeter of the PSA of the Eastern Adriatic Sea.

In the case of the port of Trieste at the Port City Territory Level, the spatial impacts are visualized in a vast territory that stretches between sea and land, involving both the system of breakwaters and the hinterland, highlighting some key junctions where the cluster's impact is most evident. These include the Intermodal Terminal of Trieste—Fernetti, which marks the traffic channel to Slovenia, and the Innoway Trieste site, recently reindustrialized for the production of high-tech railway wagons. The mapping work also collects the main forecasts of the Strategic System Planning Document (Documento di Pianificazione Strategica di Sistema, DPSS), which also involves the port of Monfalcone, in terms of new commercial terminals. It also shows the impact of the clustered port in terms of urban perception: in this context, the steep morphology marking the Italy–Slovenia national border also defines a new visual image of the port skyline. The map taken as an example here is neither intended to return the functional differentiation of the port area, nor does it necessarily refer to the port's administrative boundary. As illustrated, the map also addresses the area linking the cluster's key nodes, where each entity exists not only to share costs but also to shape a plural vision of the port within the broader integrated coastal development.

The key objectives of this mapping activity are the development of a mapping without borders (other than those of the page) and the simultaneous visualization of spatial impacts on the territory, while considering their inevitable stratification and superimposition. In line with the theoretical notion of cluster, the maps attempt to represent its impacts as a "horizontal phenomenon," thus characterized by relational dimensions and spatial articulations. Whatever their deficiencies—as already discussed in the previous paragraph regarding their incompleteness—these maps try to represents the "cluster extension."

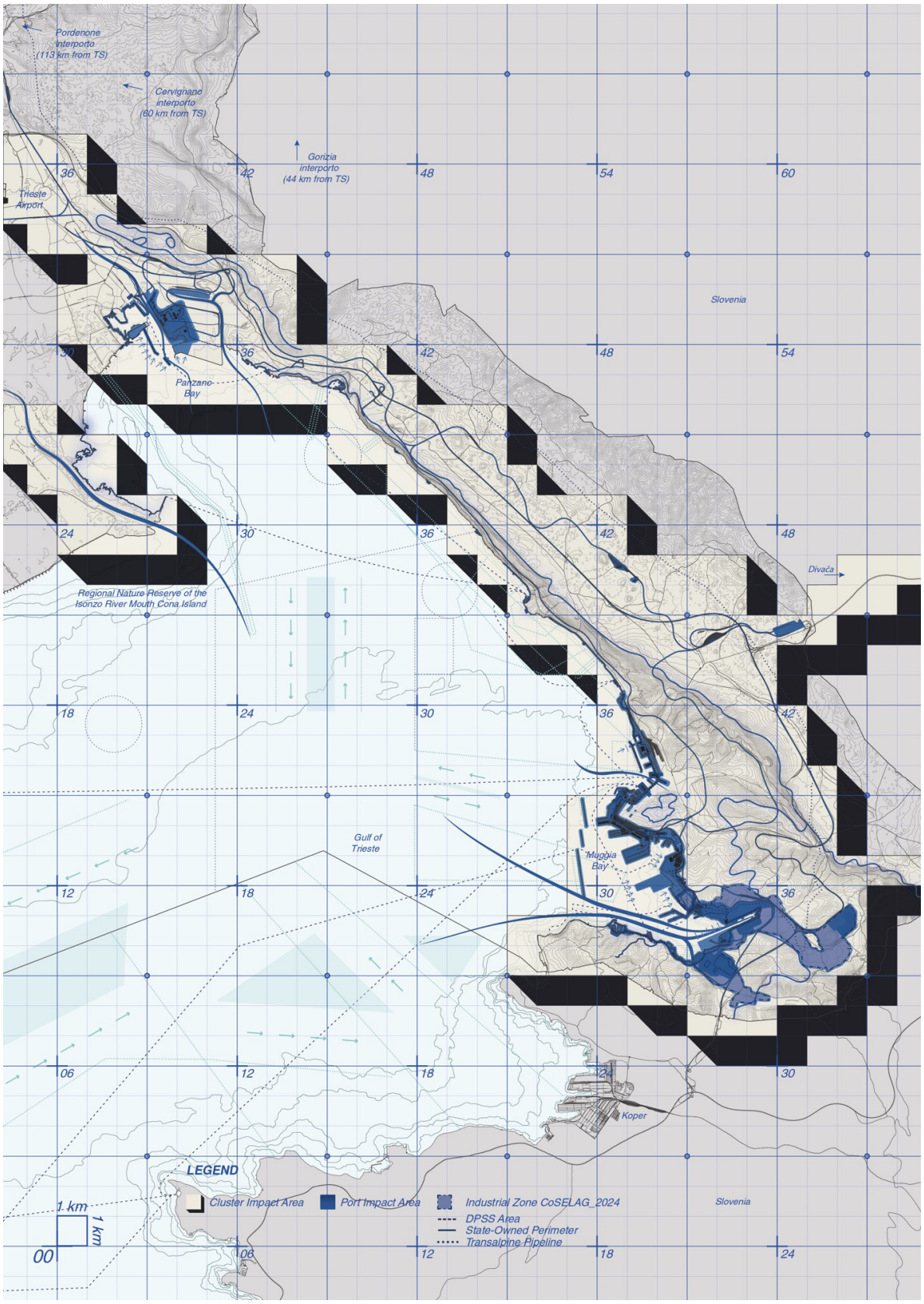

Figure 3. Atlas of Maps of the Port-Cluster Landscape, Cluster Level: Trieste and Monfalcone. Note: Figure concept and graphic elaboration by Giulia Ansaldi and Beatrice Moretti.

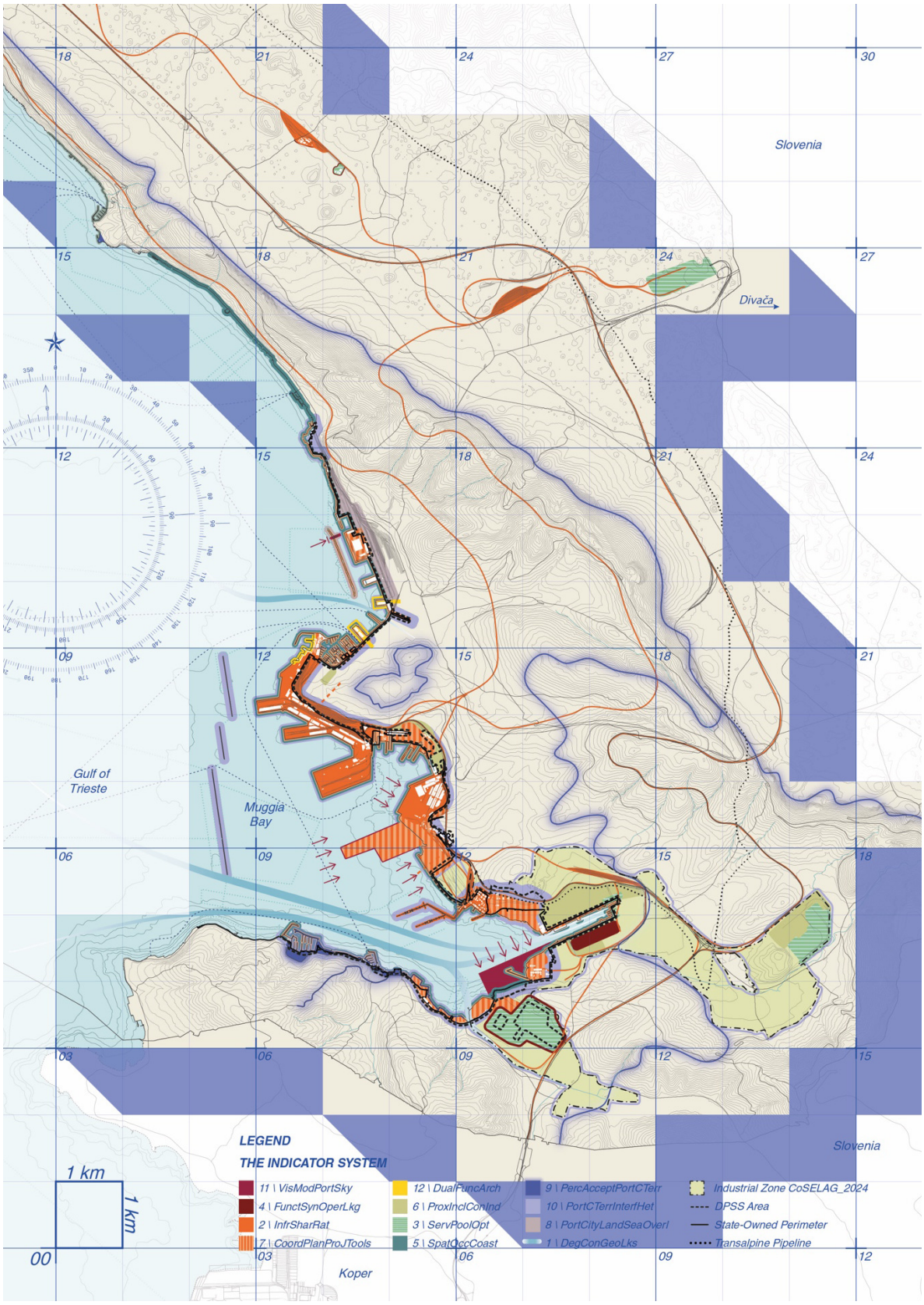

Figure 4. Atlas of Maps of the Port-Cluster Landscape, Port City Territory Level: Trieste. Note: Figure concept and graphic elaboration by Giulia Ansaldi and Beatrice Moretti.

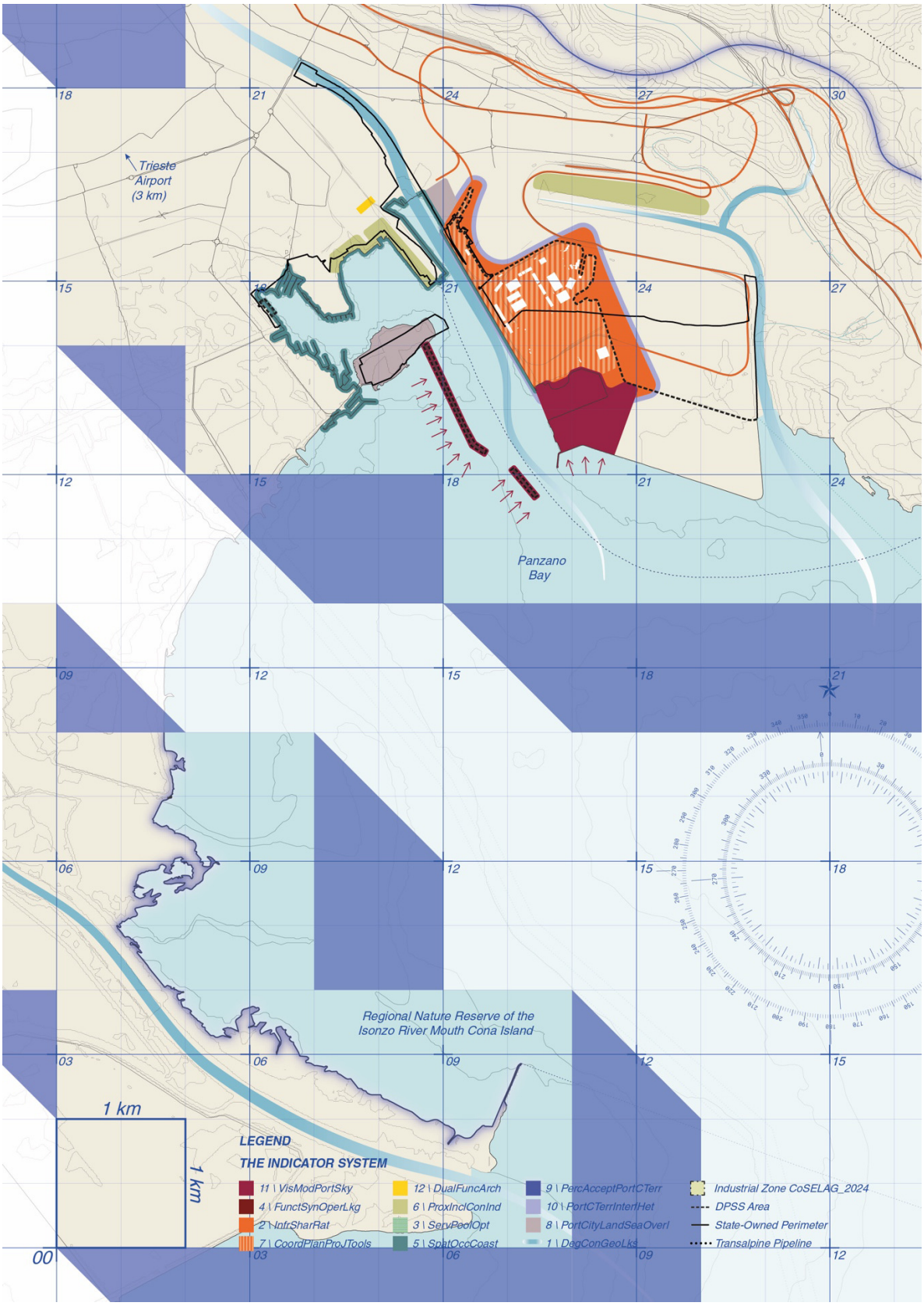

Figure 5. Atlas of Maps of the Port-Cluster Landscape, Port City Territory Level: Monfalcone. Note: Figure concept and graphic elaboration by Giulia Ansaldi and Beatrice Moretti.

The two maps developed at the Port City Territory Level are complemented by an introductory Cluster Level map that shows together the spatial impacts related to the ports of Trieste and Monfalcone, as well as framing the port of Koper in Slovenia.

The same methodological approach is in the process of being applied in the PSA of the North Tyrrhenian Sea with an overall map showing the spatial impacts of the cluster made up of the five ports (Cluster Level) and four individual maps displaying the spatial impacts in Livorno, Piombino, Capraia, Portoferraio, and Rio Marina (Port City Territory Level).

By further developing this methodology, currently tested on two Italian port city territories, it is believed that the characteristics of the port-cluster landscape will emerge more clearly, highlighting the need for new indicators to record specific impacts, or the possibility of merging, overlapping, or eliminating some of those already defined.

5. Conclusion: Embracing the Polycentricity and Polymorphism of Contemporary Port Spatiality

Port spatiality is constantly evolving. This has been the case since the dawn of ports, as their structure adapts and evolves in accordance with the ways goods are exchanged and managed between ports. If, with the growth of the logistics sector in recent decades, the role of territories has reduced its significance due to the digitalization/dematerialization of traffic, it seems that ongoing processes—such as port clusterization—can bring the spatiality of ports back to the centre.

From the application of the spatial indicators and the elaboration of the Atlas, we can preliminarily state that the port-cluster landscape is a polycentric, heterogeneous, and often disjointed set of spaces. A very extended one which is subject to the control of multiple public actors and conditioned by the funding and projects of private actors. A set of spaces in constant reconfiguration and negotiation in which partnerships between ports are rapidly multiplying: “Not only do ports increasingly organize in clusters or merge with other port managing bodies, strategic partnerships on specific topics with other seaports either at national or international level are also taken up” (ESPO, 2022, p. 19).

By acknowledging this particular type of landscape, the idea of the city–port interface will be expanded and spatial connotations will be attributed to traditional definitions of the cluster that currently lack them. With the concept of port-cluster landscape, the port cluster will have a (changeable) perimeter, its extent will be measurable (also in volumetric terms thanks to the indicators that consider the port geography and skyline), and the spatial relations between the mobility infrastructures that feed the cluster, the geographical arteries on which it hinges, and the built environment that populates the urban-port hinterland will be comprehensible. From this perspective, we can see correspondences between the concept of port-cluster landscape and the definition of “technical lands” (Galison, 2017; Nesbit & Waldheim, 2022). This further emphasizes the debate on the relationship between technical components and the spectrum of spatiality they can produce.

First design recommendations emerge regarding the 12 spatial indicators. As illustrated in the methodology, indicators will be translated into corresponding design strategies to form a Catalogue to guide the future project of port clusters. This translation is based on the idea that “urban design is in substance a normative activity

that often makes use of principles to transfer knowledge of a given urban phenomenon to the design process" (Forgaci, 2018, p. 181). Moreover, the resulting design strategies will be linked with the goals of the AIVP *Agenda 2030*: this step will be crucial to transform the results of scientific research into exploitation tools for planning. Indicators 5 "Spatial occupation of the coast" and 8 "Port-to-city & land-to-sea overlapping," e.g., can provide valid insights into the implementation of the AIVP goal of "promoting the architectural and landscape integration of port facilities" (Goal 08.4 "Port City Interface"; AIVP, 2018, p. 25). By pursuing the AIVP Goal 04.05 of "adopting a land management policy that strikes a balance between urban uses and the active port, especially on the waterfront" (AIVP, 2018, p. 17), we can exploit the insights derived from indicator 7 "Coordinated planning & project tools between ports in the cluster," 9 "Perception/acceptability of the port from/by the port-city territory," and 10 "Port-city-territory-interfaces heterogeneity."

In terms of strengths and weaknesses, research will need, in future developments, to test its methodology on a wider selection of port clusters. A broader application will make the research more reliable and flexible. The ambition to build a study based on dialogues with the PSAs, on one hand, generates a complex system of exchanges between institutions and academia based on a shared language and perspectives that often clash with their respective areas of expertise. On the other hand, this system can lead to further collaborations involving the academic field and that of territorial administration and transition.

As AIVP states in the Agenda 2030 for sustainable port cities, "port cities are today very exposed to the perverse effects of growth. In fact, in the short term, the consequences of climate change threaten their very existence" (AIVP, 2018, p. 3). In view of this, the research claims the role of port cities as indispensable players in sustainable development, by representing one of the first scientific contributions to the design of port clusters and their spatial configurations. Moreover, to position ports as key elements in the development of future living and working environments, this research aligns with the reimagining of the built environment, as proposed by Christian Schmid: "Existing urban forms are dissolving and polymorphous urban regions are taking shape. Extremely heterogeneous in structure, they include old city centres as well as formerly peripheral areas" (Schmid, 2014, p. 204). To understand the new built forms—including clustered ones—research must move beyond analysing individual cities shaped predominantly by ideal-typical models. Instead, it should embrace the polycentric and polymorphic nature of contemporary spaces, while also considering the broader impacts of global urbanization and its varied regional and local patterns.

Acknowledgments

This article is framed within the research project of excellence PULSE—The Port-clUster LandScapE: Developing a Spatial and Design Approach to Port Clusters (https://pulse.unige.it). Host Institution (HI): Università degli Studi di Genova, Dipartimento Architettura e Design—DAD. Principal Investigator (PI): PhD Arch. RtdA Beatrice Moretti. Codice Unico del Progetto–CUP (UniGe): D33C2200165000. Project code (MUR): 100027–2022-BM-PNRR-YR_SOE_0000001. The author would like to thank the Association of Italian Ports (Assoporti) for the operative support of the research activities. Thanks also go to the PSA of the Eastern Adriatic Sea (Ports of Trieste and Monfalcone), in particular to Dr. Giulia Zolia and to Dr. Giacomo Morassutti for their valuable collaboration in the mapping activities. The author would also like to thank Dr. Giulia Ansaldi for her research work and the graphic elaboration of the maps (Figures 3, 4, and 5).

Funding

Winner of the Young Researchers Call 2022, PULSE has received funding from the Italian Ministry of University and Research, as part of the implementation of the National Recovery and Resilience Plan (NRRP)—Mission 4 "Education and Research"—Component 2 "From Research to Business"—Investment 1.2 "Funding Projects Presented by Young Researchers," within Next Generation EU. For more information, please visit https://pulse.unige.it/context

Conflict of Interests

The author declares no conflict of interests.

Data Availability

The data associated with this research are available in the official PULSE research databases held by the Principal Investigator and by the Host Institution.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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Ocean and Society
2025 • Volume 2 • Article 9306
https://doi.org/10.17645/oas.9306

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ARTICLE

Open Access Journal

Between Containers and Warehouses: Rehabilitating Port Proximities in UAE Coastal Cities

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Submitted: 14 September 2024 **Accepted:** 2 December 2024 **Published:** 23 January 2025

Issue: This article is part of the issue "Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions" edited by Mina Akhavan (TU Delft), Yvonne van Mil (TU Delft), and Carola Hein (TU Delft), fully open access at https://doi.org/10.17645/oas.i442

Abstract

Len Chapman's early photographs of Port Rashid serve as an entry point into the narrative of port construction and its profound impact on global commerce and urban landscapes. These images, capturing the nascent stages of development, bear witness to the monumental transformations spurred by the construction of new ports and the modernization of historical ones in the UAE. The rapid economic and urban growth in the UAE, exemplified by projects like Port Rashid, reflects broader shifts in Gulf port geopolitics and global trade dynamics. The emergence of megaports and the era of containerization have reshaped maritime infrastructure and trade routes. This gave rise to unintended consequences, such as the disruption of coastal urban fabrics and the emergence of residual unsolved spaces. Recent recovery and rehabilitation processes like "districtification," museumification, and cultural reuse raise critical questions about long-term sustainability, public access preservation, and achieving a balance between passive and active engagement with port proximities. This article delves into specific case studies, including the Al Hamra ghost village, Al Shindagha, and MIZA Abu Dhabi to explore the impacts of maritime capitalism on urban and cultural landscapes. These sites reveal the challenges of balancing economic growth with sustainable urban recovery efforts, including "districtification," museumification, and cultural reuse. The analysis underscores the complexities of ensuring long-term sustainability, public access, and active engagement in port-adjacent areas. By adopting descriptive and comparative methodologies, this research aims to deepen the understanding of how maritime commerce shapes coastal urban areas in the UAE. The study contributes to discussions on sustainable urban development and heritage preservation, emphasizing the need for mindful urban planning in the Gulf's rapidly evolving and economically competitive landscape.

Keywords

coastal urban fabrics; cultural reuse; heritage preservation; port construction; maritime capitalism; museumification; port-city; port proximities; UAE; urban landscapes

1. Introduction

The evolution of coastal cities in the UAE, particularly Dubai, offers a compelling case study of how globalization has reshaped the Gulf region's drive for commercial competitiveness. In response to intensifying global market demands, Gulf countries have strategically leveraged their coastal locations to position themselves as crucial nodes in international trade networks. Historically, ports have been central to urban development, serving as vital engines of economic growth and connectivity. In the UAE, the development of major ports such as Port Rashid and Jebel Ali was not merely a reaction to global economic pressures, but also a strategic endeavour to secure a competitive edge within the region.

Compared to traditional port-city models seen in Europe and Asia, the UAE's approach is distinctive. It is shaped by a blend of internal drivers, oil revenues, government-led initiatives, and rapid modernization. The velocity of these transformations became a critical factor in shaping new urban landscapes while reshaping and reverse-shaping port-proximity landscapes. Akhavan (2017) notes that this strategic integration of history and modernization is evident in Dubai's use of free trade zones and specialized economic zones, which not only support economic diversification but also symbolize the UAE's progress.

However, the UAE's drive toward economic modernization has been carefully balanced with the preservation of national identity and cultural heritage. The state has skillfully navigated the challenge of integrating modern infrastructure while maintaining continuity with its national narratives. Drawing on Bauman's (2000) concept of liquid modernity, the UAE has adopted a flexible approach to its historical legacy, selectively utilizing elements of its past to construct a cohesive national identity aligned with its ambitious economic objectives.

On the surface, the UAE's rapid port expansions and urban transformations appear fluid, reflecting an ability to adapt seamlessly to global trends. Yet, beneath this adaptive exterior lies a meticulously planned, state-led framework that ensures controlled development. This duality—a flexible outward image paired with a tightly controlled internal structure—enables the UAE to project an image of agility while maintaining oversight over its developmental trajectory. The strategic use of elements like museumification, "districtification," and performative urban planning demonstrates the UAE's sophisticated approach to shaping urban spaces and social interactions.

1.1. Methodology

This article employs a multi-faceted approach that includes a conceptual framework based on Bauman's (2000) liquid modernity, exploring the fluidity of urban spaces near major ports and how global commerce intersects with national identity. It features a literature review of key concepts like museumification and performativity, setting the theoretical backdrop for the redevelopment of heritage districts. The study also conducts a comparative case study analysis of five heritage districts, using visual documentation and descriptive methods to examine how these spaces balance preservation with active reuse, particularly concerning their proximity to ports. Additionally, a visual and descriptive analysis of photographs and other materials provides tangible evidence of the spatial and cultural transformations in these areas, offering insight into the physical and functional shifts occurring in these historical districts.

2. Theoretical Context

2.1. UAE's Port-City Model

UAE's port model and Dubai's model have evolved over four phases. Phase I (1900s–1950s): Dubai emerged as a free port, fostering early trade and settlement growth around Dubai Creek; Phase II (1960s–1970s): The discovery of oil and the establishment of modern urban planning (e.g., Port Rashid) positioned Dubai as an entrepôt city; Phase III (1980s–1990s): Dubai transitioned into a regional transhipment hub with infrastructure like Jebel Ali Port and free trade zones; Phase IV (2000s–present): Dubai evolved into a logistics hub integrating air, land, and sea transportation, with extensive free trade zones and mega projects such as Dubai World (Akhavan, 2017). However, it is crucial to recall the differences between the Western, Asian, and UAE port models. As highlighted by Akhavan (2017), who notes that Dubai's approach diverges from these paradigms.

The Western port-city model has evolved gradually over centuries, shaped by industrialization and urban growth. Ports and cities became spatially and economically distinct as industrial ports moved to accommodate larger-scale operations, leaving waterfronts for urban redevelopment. For instance, London transformed its former docks into the Canary Wharf financial district. Similarly, the Asian port-city model has been driven by globalization, industrialization, and colonial legacies, emphasizing the integration of port activities within urban and economic structures. This model's development stages range from colonial city ports to free-trade hubs and global logistics centres, maintaining an interdependent relationship between cities and ports. Cities such as Singapore, which transitioned from a colonial entrepôt to an integrated global logistics hub, and Hong Kong, where dense urban growth coexists with significant port activity, exemplify this integrated approach.

In contrast, the UAE's port-city model reflects a rapid, government-led transformation achieved within decades, fueled by oil revenues. This model focuses on integrating ports with urban development through strategic infrastructure investments and the establishment of free trade zones. Port operations, such as those at Jebel Ali Port, are combined with multi-use urban spaces like Dubai Maritime City. Unlike the gradual evolution of Western models, the UAE's approach prioritizes the speed of development and avoids the spatial and functional segregation typically seen in Western cities. Dubai's model merges port and urban development, maintaining the centrality of ports to the economy in a way that contrasts with the declining significance of ports in Western cities. This approach blends elements of Western urban redevelopment and Asian port-city integration while retaining its government-led transformation strategy. Features such as free trade zones, multi-modal logistics hubs, and global connectivity underscore its distinct approach to port-city development (Akhavan, 2017). The rapid pace of development and the absence of spatio-functional segregation have significantly impacted urban spaces near the ports, resulting in unresolved spatial dynamics. The following sections explore strategies used to address these challenges through the lenses of fluidity, performativity, and museumification.

2.2. Fluidity: Navigating Fluidity and Stability in the UAE

Bauman's (2000) concept of liquid modernity describes the increasing fluidity of social and spatial structures as globalization accelerates. In the UAE, fluidity is not merely a theoretical abstraction but a practical reality, as seen in the constant adaptation of urban spaces to the demands of global trade. Ports like Jebel Ali and Port

Rashid exemplify this fluidity, serving as ever-evolving hubs that integrate air, land, and sea transportation to maintain their relevance in a competitive global economy.

In the UAE however, fluidity is mediated by a state-directed model that prioritizes national cohesion and cultural preservation alongside economic modernization. Rather than allowing fluidity to dominate, the UAE implements a highly coordinated framework that channels global influences while maintaining a strong sense of local identity. For Emirati citizens, this framework provides stability by reinforcing cultural heritage and traditions, even in rapidly transforming urban areas. Conversely, for expatriates—who make up the majority of the UAE's population—fluidity is experienced through transient work arrangements and temporary living conditions, creating a cosmopolitan but impermanent social fabric (Kanna, 2011).

The UAE's approach to managing fluidity is both strategic and deliberate. Ports and their proximities become zones of cultural negotiation, where global commerce intersects with local heritage. This creates a dynamic interplay between fluidity and rootedness, as areas like Al Shindagha are redeveloped to reflect the UAE's cultural heritage while adapting to the functional demands of modern urban life (Damluji, 2006). The UAE's model, therefore, does not simply "balance" fluidity and stability but reconfigures them into a synergistic relationship, ensuring that national identity is not subsumed by global forces but enhanced through selective integration.

2.3. Districtification: Integrating Heritage and Urban Growth

Districtification in the UAE represents a deliberate strategy to transform urban spaces into multifunctional zones where heritage preservation and contemporary development coexist. This concept aligns closely with the UAE's vision of creating culturally significant spaces that remain economically and socially relevant. Unlike Western cities, where redevelopment often segregates historical zones from modern ones, the UAE integrates these elements into cohesive districts. In this way, districtification becomes a tool not just for urban planning but for nation-building.

The spatial implications of districtification are evident in projects like the Heart of Sharjah, where traditional Emirati architecture is preserved while new cultural and commercial facilities are introduced. These heritage districts are carefully curated to serve as living spaces that blend past and present, creating a sense of continuity even as urban growth accelerates. Socially, districtification transforms heritage sites into active public spaces that foster community engagement. By hosting events, exhibitions, and cultural activities, these districts become performative arenas where residents and visitors alike can connect with Emirati traditions (Boussaa et al., 2023).

In the UAE context, districtification is more than a spatial strategy; it is a state-directed effort to define and reinforce a cohesive national identity. This approach ensures that while global commerce reshapes the city's economic landscape, its cultural and social foundations remain intact.

2.4. Managing Fluidity in Ports and Urban Spaces

As the UAE integrates its ports into the global economy, the surrounding urban spaces have become critical arenas for negotiating cultural identity and modern development. The state employs strategies such as

museumification and districtification to shape these port-adjacent spaces, blending traditional Emirati heritage with the demands of global commerce (Boussaa et al., 2023). Al Shindagha in Dubai and the Heart of Sharjah are examples where these strategies are implemented to transform heritage sites into spaces that balance preservation and functionality. Through these interventions, the UAE showcases that modernity and cultural continuity are not inherently oppositional but can coexist in carefully curated urban environments.

The Heart of Sharjah project and the Al Shindagha Museum district illustrate how proximity to global trade infrastructure influences the spatial and social significance of heritage sites. These areas are not merely preserved as static artefacts but are reimagined to support the UAE's nation-building agenda. By incorporating museums, art spaces, and cultural projects into these historically significant areas, the UAE ensures that while the physical landscape evolves to accommodate trade, the cultural landscape remains firmly rooted in Emirati traditions. This approach recontextualizes heritage to fit within the UAE's modern narrative, reinforcing national identity amidst globalization.

The UAE's management of fluidity in these spaces is deliberate and multifaceted. While Bauman's (2000) concept of liquid modernity emphasizes the destabilizing effects of globalization on national identities, the UAE redefines this dynamic by implementing state-directed frameworks that mediate between global commerce and local heritage. Ports like Port Rashid and Jebel Ali exemplify this interplay, where urban development is regulated to ensure that these spaces remain economically vital while also culturally significant. By transforming port proximities into performative spaces that host events, exhibitions, and regeneration projects, the UAE aligns economic imperatives with cultural preservation. This proactive approach exemplifies how the UAE navigates the challenges of globalization by turning fluidity into an opportunity to reassert cultural identity.

2.5. Museumification and Performativity: Definitions and Applications

Museumification and performativity represent two key strategies through which the UAE engages with its heritage spaces. Museumification refers to the transformation of historical sites into curated spaces that emphasize preservation and education. This approach is exemplified by districts like Al Shindagha, where traditional Emirati architecture is meticulously conserved to reflect the nation's cultural legacy. However, unlike static museumification models seen elsewhere, the UAE integrates these sites into the urban fabric, ensuring they remain active contributors to social and cultural life. By hosting exhibitions, educational programs, and cultural events, these spaces are repositioned as dynamic cultural hubs that attract both local and international audiences (Damluji, 2006). This recontextualization ensures that heritage is not only preserved but also reinterpreted to align with contemporary narratives.

Performativity has emerged as a significant concept in urban architectural discourse, encompassing a wide semantic range that includes flexibility, dynamic spatial settings, event-based spaces, and active engagement with both space and context. A review of the literature highlights various interpretations of performativity.

At its core, performativity refers to the open and adaptable nature of space, which invites improvisation and change (Signore, 2015). It is also associated with the scenic and theatrical qualities of spaces that evoke specific moods or atmospheres (Janson, 2015). The concept captures the interplay between intentional and unintentional elements, the planned and the unplanned, emphasizing a space's readiness to evolve beyond its original intended use (Leatherbarrow, 2005).

Moreover, performativity suggests a project in progress, characterized by networked and non-linear mechanisms (McKenzie, 2002). It enables architecture to transcend disciplinary boundaries, incorporating tools from performance art (Lavin, 2012). Performative-oriented spatial design highlights a space's ability to perform multiple functions simultaneously and to convey meaning (Kassem, 2022).

The transformative nature of performative spaces lies in their capacity to restructure spatial and social orders by influencing both audience and context (Carlson, 2008). Brüeckner's (2008) concept of "making spaces talk" illustrates this idea, suggesting that performative spaces actively engage with users through design, choreography, and dramatization (Atelier Brückner, 2011). This dynamic is evident in UAE heritage sites like the Heart of Sharjah, where the interaction between architecture, cultural programming, and social participation creates a vibrant cultural ecosystem.

Performative spaces transform heritage into interactive environments that invite active participation. Sites such as the Heart of Sharjah and the Al Shindagha Museum district host a variety of activities, including public performances, art installations, and community gatherings. These spaces blur the line between historical and contemporary, allowing heritage to be experienced rather than merely observed. As von Hantelmann (2014) notes, performative spaces transform visitors into participants, positioning the heritage site as an active agent in cultural production.

In contrast to museumification, performativity reinvigorates historical spaces by encouraging adaptive reuse and continuous reinterpretation (Kassem et al., 2024). The UAE's application of these strategies is particularly significant in port-adjacent districts. Historical sites such as Al Jazeera Al Hamra in Ras Al Khaimah and the Old Heart of Sharjah, once neglected due to modernization, have been revitalized through a blend of museumification and performativity. These spaces now serve dual purposes: preserving cultural heritage while accommodating contemporary uses that foster community engagement. This holistic approach ensures that historical districts are not isolated relics but integral parts of the urban fabric, reflecting the UAE's commitment to bridging past and present.

3. UAE Port Cases: Rehabilitating Port Proximity Sites

In the following discussion, we examine the performative approach to the reuse of historical districts in the UAE. While museumification typically emphasizes preservation and a more conservative approach, performativity is dynamic and interactive, embracing both change and modernity. The approach selected for any given district depends on the cultural, economic, and educational objectives set by those managing the heritage. In some cases, districts blend both strategies, balancing the desire for historical preservation with the need for active community engagement.

Our analysis of the five case studies (the Old Heart of Sharjah, Al Shindagha in Dubai, MIZA in Abu Dhabi, Al Jazeera Al Hamra in Ras Al Khaimah, and Umm Al Quwain) focuses on key criteria that define the relationship between heritage and urban regeneration. These include the nature of public engagement (whether passive or active), the heritage presentation strategy (such as adaptive reuse or reconstruction), and the intensity of presence and occupancy (ranging from occasional to continuous use).

Additionally, the analysis explores the heritage processing approach (whether oriented towards museumification or performativity), the specific cultural objectives driving each project, and the functional uses of each space (whether monofunctional or multifunctional). It also considers the presence and accessibility of public spaces, the site's connectedness to the broader urban context, and the degree of spatial intervention (whether fixed or adaptable to future changes). Finally, the proximity of the site to new port developments and its impact on the site's role and opportunities are also assessed.

3.1. Case 1: Heart of Sharjah, Sharjah

3.1.1. Background and Historical Significance

The Heart of Sharjah stands out as one of the UAE's most significant urban regeneration projects, reflecting the Emirate's rich history as a centre of trade and cultural exchange. Historically, this district was integral to Sharjah's role as a prominent trading hub in the Arabian Gulf, benefiting from its strategic location on the Trucial Coast (Al-Sayegh, 1998). From the 19th century onwards, Sharjah thrived on pearl trading and maritime commerce, with its port facilitating connections with India, Persia, and East Africa. Over time, modernization and urbanization threatened its historical fabric, prompting conservation efforts to preserve and showcase the district's architectural and cultural heritage.

The Heart of Sharjah initiative aims to restore the historical essence of the area while incorporating modern amenities. The project emphasizes the preservation of traditional souks, mosques, and residences, all of which embody the architectural vernacular of the region. By doing so, it not only preserves Sharjah's cultural legacy but also positions the district as a dynamic space for contemporary use.

3.1.2. Key Architectural and Urban Planning Features

The conservation of the Heart of Sharjah is a case of radical conservation; the historical district was largely reconstructed following its earlier demolition and replacement with modern buildings. Despite appearing as a light intervention, the project represents a significant transformation aimed at reviving the vernacular architectural aesthetic. Narrow shaded streets, whitewashed façades, and intricately carved wooden doors were meticulously recreated to reflect Sharjah's architectural heritage while incorporating modern infrastructure for contemporary functionality, such as discreet air-conditioning and advanced lighting systems (Damluji, 2006).

The approach extends beyond mere reconstruction. Many of the newly restored buildings have been repurposed as art galleries, cultural venues, and educational spaces, seamlessly blending historical preservation with active modern use. The Sharjah Art Foundation (SAF) has been instrumental in this transformation, leveraging the district's recreated historical setting as a platform for artistic and cultural innovation. Through a diverse array of exhibitions, performances, and workshops, the SAF has reimagined the Heart of Sharjah as a dynamic and interactive cultural hub that bridges Sharjah's historical legacy with its contemporary aspirations.

3.1.3. Historical Overview and Relationship to the Port

Sharjah's historical district was deeply tied to its port, which once served as the economic and social nucleus of the Emirate. However, mid-20th-century modernization efforts, which saw much of the old town replaced by modern infrastructure, disrupted this symbiotic relationship, severing the district from its waterfront roots (Boussaa, 2023). The Heart of Sharjah project represents a bold attempt at radical conservation, reconstructing the historical framework that had been lost to modernization. This endeavour not only seeks to revive the district's vernacular urban aesthetic but also aims to reintegrate it into Sharjah's broader urban context, ensuring that heritage remains central to the Emirate's cultural identity.

The reconstruction effort, while ambitious, is not without its implications. By rebuilding large portions of the district, the project walks a fine line between authenticity and reinvention. While this approach preserves the spirit of Sharjah's past, it raises questions about the balance between historical accuracy and the practical need to make heritage sites functional in a contemporary context.

3.1.4. Performative Approach: The Role of the SAF

A distinctive element of the Heart of Sharjah project is its move beyond traditional preservation toward radical conservation with a performative dimension. This approach, spearheaded by the SAF, transforms the district into a cultural and artistic hub, reactivating its spaces for contemporary use. SAF programming—including artist residencies, public art projects, and educational workshops—imbues the district with vibrancy, ensuring that its reconstructed spaces serve as platforms for cultural and community engagement.

The interplay between reconstructed historical elements and dynamic cultural activities enhances the district's identity as a living museum. However, the performative approach also highlights the tensions inherent in balancing the reconstructed district's historical narrative with the demands of contemporary cultural programming, illustrating the delicate balance required in radical conservation efforts.

3.1.5. Challenges and Opportunities

While the Heart of Sharjah project has successfully reconstructed and revitalized the district, its reliance on radical conservation introduces unique challenges. Rebuilding parts of the historical framework from scratch, while visually compelling, raises critical questions about the authenticity of the heritage it seeks to preserve. This approach risks creating a "staged" version of history that may alienate local communities who remember the area's pre-modernization form. Reconciling these tensions will require a careful narrative framing that integrates the reconstructed elements into Sharjah's living cultural memory.

Furthermore, the episodic nature of the district's current activity highlights a need to sustain daily engagement beyond seasonal cultural programming. Radical conservation offers an opportunity to embed these spaces more deeply into the social and economic fabric of the city by introducing mixed-use functions, such as integrating residential units for local artists and residents, small-scale retail spaces that reflect the area's traditional trade practices, cafes and restaurants catering to both tourists and locals, co-working spaces for creative professionals, and studios for art and cultural production. These elements can foster a dynamic, year-round presence that balances tourism with local use.

Finally, radical conservation has significant implications for long-term urban sustainability. By ensuring that reconstructed spaces are adaptable to future needs without losing their historical essence, the project can evolve beyond static heritage preservation. This will require continuous community involvement and innovative urban planning to position the district as a model for balancing heritage and modernity in rapidly urbanizing contexts.

3.2. Case 2: Al Shindagha District, Dubai

3.2.1. Background and Location

Al Shindagha, one of Dubai's most historic neighbourhoods, occupies a prominent position along the bustling Dubai Creek. Historically, the district served as a residence for the ruling Al Maktoum family and was a vital hub for trade, governance, and social life in the city. Its strategic location along the creek cemented its importance as a maritime gateway, connecting Dubai to key trading networks in India, East Africa, and Persia. Over time, Al Shindagha evolved into a symbol of Dubai's cultural heritage, culminating in the establishment of the Al Shindagha Museum district. This district now houses cultural landmarks such as the story of the Creek Museum, Al Maktoum Museum, and the Perfume Museum, each underscoring Al Shindagha's integral role in Dubai's historical narrative.

3.2.2. Key Architectural and Urban Planning Features

Al Shindagha exemplifies a conservation effort that balances traditional architecture with modern needs, reflecting a nuanced approach to museumification. The district's restoration prioritized the use of authentic materials such as mud-brick façades and preserved architectural elements like wind towers (*Barjeel*) and courtyard layouts. However, discreet modern interventions—such as climate control and public infrastructure—were integrated to support its contemporary functionality as a cultural hub (Al Amiri, 2020).

Public spaces within Al Shindagha were redesigned to accommodate both passive and active cultural experiences, bridging heritage preservation with modern urban engagement. This thoughtful design facilitates the coexistence of static exhibitions with dynamic programming, creating a layered urban experience.

3.2.3. Historical Overview and Relationship to the Port

Dubai Creek was historically the lifeline of the city's economy, positioning Al Shindagha as an epicentre for trade and commerce. The district thrived as a maritime hub, facilitating the exchange of goods such as pearls, spices, and textiles. However, the construction of modern port infrastructure, including Port Rashid in the 1970s, marked a turning point in Dubai's maritime economy. The focus shifted from the creek to larger, more centralized shipping hubs, leading to the gradual transformation of Al Shindagha into a heritage district. While its role as a commercial hub diminished, the district's redevelopment aims to restore its significance within Dubai's urban fabric, now reframed as a cultural and historical focal point.

3.2.4. Performative Approach

Although Al Shindagha is predominantly characterized by museumification, performative elements have been incorporated into its cultural programming. The district regularly hosts temporary exhibitions, cultural festivals,

and educational workshops, utilizing its courtyards and public spaces as venues for interactive engagement. These activities enhance the visitor experience by integrating historical narratives with contemporary forms of cultural expression. However, the performative aspect remains secondary, with much of the district's life driven by tourism rather than sustained local engagement.

3.2.5. Challenges and Opportunities

The district faces the ongoing challenge of balancing cultural preservation with commercialization. Over-reliance on tourism-driven programming risks alienating local communities and creating a static cultural showcase rather than a living, dynamic heritage space. To address this, Al Shindagha must develop strategies to attract diverse audiences, including residents, through programming that integrates everyday activities with cultural preservation.

Incorporating mixed-use developments, such as creative workspaces and residential components, could further enhance the district's vibrancy. Strengthening the connection between Al Shindagha and Dubai's broader urban framework, particularly its proximity to Port Rashid, presents an opportunity to bridge the district's historical identity with its modern context.

3.3. Case 3: MIZA Project, Abu Dhabi

3.3.1. Background and Location

The MIZA project represents Abu Dhabi's ambitious attempt to transform the historical Mina Zayed port area into a vibrant cultural and creative hub. Established in the 1970s as Abu Dhabi's primary port, Mina Zayed was pivotal in the city's development, facilitating the import and export of goods during a period of rapid urbanization. However, the emergence of the larger Khalifa Port in 2012 rendered Mina Zayed underutilized, leaving much of its infrastructure abandoned. The MIZA project seeks to breathe new life into this industrial space by repurposing its warehouses into art studios, educational facilities, and event venues, positioning it as a cornerstone of Abu Dhabi's cultural economy.

3.3.2. Key Architectural and Urban Planning Features

The adaptive reuse of Mina Zayed's industrial architecture lies at the heart of the MIZA project. The initiative transforms shipping containers and warehouses into multifunctional spaces, showcasing a commitment to sustainability and innovation. The project retains much of the original street grid while incorporating pedestrian pathways and landscaped public spaces, creating a balance between historical character and modern urban accessibility (Al Amiri, 2020).

Key interventions include integrating green spaces and cultural venues into the area, fostering both social interaction and environmental sustainability. By blending industrial heritage with creative industry requirements, the project reflects Abu Dhabi's vision for a culturally enriched urban future.

3.3.3. Historical Overview and Relationship to the Port

Mina Zayed played a significant role in Abu Dhabi's emergence as a regional trading hub, handling a substantial portion of the UAE's container traffic during the 1970s and 1980s. With the relocation of port activities to Khalifa Port, the site's relevance waned, leaving an industrial void in the city's landscape. The MIZA project seeks to redefine Mina Zayed's legacy by preserving its industrial heritage while aligning it with Abu Dhabi's cultural ambitions.

3.3.4. Performative Approach

The MIZA project actively incorporates performative strategies through dynamic cultural programming. Temporary art installations, maker events, and creative workshops animate the repurposed warehouses, transforming them into sites of active engagement. This performative approach ensures that the project remains flexible and adaptive, accommodating both short-term events and long-term cultural initiatives.

3.3.5. Challenges and Opportunities

The MIZA project must navigate the challenge of maintaining cultural relevance while addressing logistical hurdles such as accessibility. Its location, though historically significant, is somewhat removed from Abu Dhabi's central cultural districts, necessitating sustained efforts in marketing and infrastructure development.

To ensure the project's long-term success, it must balance the creative community's needs with those of commercial stakeholders. Expanding the project's scope to include more mixed-use developments could enhance its integration into Abu Dhabi's urban fabric, fostering continuous engagement across diverse audiences.

3.4. Case 4: Al Jazeera Al Hamra, Ras Al Khaimah

3.4.1. Background and Location

Al Jazeera Al Hamra is a historic village located in the southern part of the emirate of Ras Al Khaimah. Once a bustling pearling town, the village thrived during the early 20th century, with its economy heavily reliant on the pearling industry and its proximity to the sea. However, by the mid-20th century, the village was abandoned as its residents relocated to modern urban centres, driven by economic shifts following the decline of the pearling industry and the rapid development of the UAE's oil-driven economy (Heard-Bey, 2004). Today, Al Jazeera Al Hamra stands as a ghost village, largely intact and offering a rare glimpse into traditional Emirati life and architecture before the oil boom. Its partial restoration has transformed it into a site of cultural and historical significance, attracting scholars, tourists, and cultural events.

3.4.2. Key Architectural and Urban Planning Features

The architectural features of Al Jazeera Al Hamra reflect the vernacular building techniques of early 20th-century coastal villages in the UAE. The village comprises coral-stone houses, traditional courtyards,

and defensive watchtowers—all emblematic of the era's architectural style. The preservation efforts have focused on stabilizing the structures and maintaining the integrity of the original materials, with minimal modern interventions (Al Amiri, 2020). The urban layout of narrow alleyways and open courtyards remains unchanged, offering insight into the historical urban planning of the village. This preservation strategy allows the site to serve as an educational tool for understanding the architecture and community life of pre-oil Emirati society.

3.4.3. Historical Overview and Relationship to the Port

Al Jazeera Al Hamra's historical relationship to the sea was integral to its development as a pearling town. The village's proximity to the port allowed residents to engage in maritime trade and pearl diving, activities that formed the backbone of the local economy. However, as Ras Al Khaimah's modern port infrastructure developed and the pearling industry collapsed in the mid-20th century, the village's economic relevance declined, and its residents moved to urban centres. Today, the area is largely abandoned, though part of it has been repurposed to house foreign workers. The section of the village that is slightly remote from the port and sea is undergoing renovation and reconstruction, with the restored portions already hosting cultural activities such as the RAK Fine Arts Festival, which highlights the site's evolving role in cultural preservation and artistic engagement.

3.4.4. Performative Approach

Al Jazeera Al Hamra offers a distinct form of performative engagement, one that is more passive and reflective compared to other heritage sites. The village is primarily experienced as a quiet, contemplative space, where visitors can explore its ruins and reflect on life in a pre-oil Emirati village. The performative elements are subtle, occasionally activated through cultural events and film productions that take place in the village. The RAK Fine Arts Festival is a notable example of how the site integrates contemporary art and heritage, offering a juxtaposition of modern artistic expression within the preserved traditional environment.

3.4.5. Challenges and Opportunities

The most pressing challenge for Al Jazeera Al Hamra is sustaining its identity as a "ghost village" while integrating it into contemporary cultural frameworks. Radical conservation of its vernacular architecture offers an opportunity to preserve its historical authenticity. However, efforts to enhance visitor engagement must remain sensitive to the site's contemplative nature. Developing a balance between passive reflection and more active programming, such as cultural festivals and interactive exhibits, could attract broader audiences without compromising the village's unique atmosphere.

Additionally, its isolated location presents both a challenge and an opportunity. While the village's remoteness reinforces its historical narrative, improving accessibility through enhanced infrastructure and curated visitor experiences could elevate its profile within the UAE's cultural tourism landscape.

3.5. Case 5: Umm Al Quwain Heritage District, Umm Al Quwain

3.5.1. Background and Location

The Umm Al Quwain Heritage district is located in one of the UAE's least developed emirates, offering a unique lens into the country's pre-modern way of life. Unlike the rapid urbanization experienced in other parts of the UAE, Umm Al Quwain has developed at a slower pace, allowing its heritage district to retain much of its original character. The district is a repository of traditional Emirati architecture, including wind towers, mud-brick houses, and defensive fortifications, which once served as the centre of governance and community life. Today, the area is undergoing restoration efforts to repurpose these structures for tourism and cultural engagement, offering visitors a contrast to the more modernized urban centres of the UAE.

3.5.2. Key Architectural and Urban Planning Features

The restoration of Umm Al Quwain Heritage district emphasizes preserving the aesthetic and architectural integrity of its historical structures while adapting them to modern uses. Traditional design elements, such as narrow alleys, open courtyards, and wind towers, have been carefully maintained to ensure authenticity (Al Amiri, 2020). These efforts reflect a commitment to preserving the urban fabric of the pre-modern settlement while introducing functionality through adaptive reuse.

Buildings within the district have been repurposed as museums, cultural centres, and exhibition spaces, fostering cultural and educational engagement. However, the district's urban planning remains relatively static, with limited integration of dynamic spaces for contemporary uses. This has resulted in an architectural landscape that prioritizes preservation over versatility, highlighting the need for future interventions to make the district more accessible and multifunctional.

3.5.3. Historical Overview and Relationship to the Port

Historically, the heritage district was closely linked to Umm Al Quwain's port, which facilitated the emirate's trade and commerce. The port's role in connecting the region to broader maritime networks positioned the district as a vital economic hub. However, mid-20th-century modernization efforts shifted economic activity away from the port, leaving the surrounding areas underutilized. Today, the port and its vicinity are characterized by neglect, with wastelands and abandoned infrastructure overshadowing the district's cultural significance.

Efforts to regenerate the waterfront area are underway, with plans to integrate the heritage district into Umm Al Quwain's broader urban framework. These developments aim to restore the historical connection between the district and the port, transforming the area into a cohesive cultural and tourism destination. This reintegration is pivotal to the district's long-term sustainability and its ability to attract both local and international audiences.

3.5.4. Performative Approach

Currently, Umm Al Quwain's heritage district exhibits limited performative engagement, with conservation efforts primarily focused on static presentations of heritage through museums and exhibitions. Although

occasional cultural festivals and events have been held in the district, these activities lack the frequency and scale necessary to establish a dynamic cultural ecosystem.

The district holds significant potential for adopting a more performative approach, wherein spaces are activated through regular programming that fosters interaction between visitors and the historical environment. For example, integrating public art installations, live performances, and community workshops could transform the district into a living cultural space, enhancing its relevance and appeal. Expanding the range of activities to include participatory events would enable the district to evolve into a site of active cultural production rather than a passive historical showcase.

3.5.5. Challenges and Opportunities

Umm Al Quwain Heritage district faces several critical challenges. Its relative isolation from more developed areas of the emirate, coupled with the neglected state of the nearby port, hinders its accessibility and reduces its appeal to visitors. Furthermore, the district's current reliance on static presentations of heritage limits its ability to engage diverse audiences and foster sustained community involvement.

Despite these challenges, the district presents unique growth opportunities. The emirate's ongoing waterfront redevelopment initiatives offer a chance to revitalize the heritage district by enhancing its connectivity and drawing greater tourist traffic. These developments, if carefully managed, could position the district as a cultural and tourism hub that balances historical preservation with modern functionality.

To achieve this, the district must transition from a conservation-focused model to a more integrated approach that incorporates mixed-use development and performative programming. Introducing residential, commercial, and creative industries into the district would ensure year-round vibrancy while fostering local engagement. Additionally, emphasizing sustainable design and community participation in future projects could reinforce the district's role as a living cultural landscape, ensuring its long-term relevance and sustainability.

4. Synthesis and Key Findings

The UAE's heritage strategies reflect a deliberate and sophisticated negotiation between preserving historical authenticity and fostering dynamic cultural engagement. This dual approach—anchored in the interplay between museumification and performativity—has allowed heritage sites to function as both cultural repositories and active urban spaces. Museumification, as exemplified by projects like the Al Shindagha Museum, emphasizes static conservation, focusing on preserving architectural and historical integrity while offering educational and tourism value. In contrast, performativity, demonstrated by the SAF's initiatives, reimagines heritage spaces as dynamic platforms for cultural participation, ensuring their integration into contemporary urban and social life.

This synthesis of strategies responds directly to the UAE's rapid urbanization and modernization. Museumification secures historical narratives and tangible cultural assets, reinforcing national identity and continuity. Meanwhile, performativity ensures these spaces remain relevant by adapting to shifting urban needs and cultural expectations, resonating with a global and local audience. Together, these approaches highlight the UAE's strategic vision: to create heritage frameworks that are simultaneously preservative and innovative, enabling these spaces to serve as vital contributors to cultural, social, and economic growth.

A unifying theme across the case studies is the role of cultural districtification, where historical districts are transformed into multi-dimensional cultural hubs. Projects such as the Heart of Sharjah and the MIZA project in Abu Dhabi demonstrate how adaptive reuse can infuse underutilized heritage spaces with new life, integrating creative industries, fostering urban regeneration, and attracting international audiences. Districtification aligns seamlessly with the UAE's broader ambitions for economic diversification and global cultural prominence, leveraging heritage as a key driver of urban development.

However, these transformations are not without challenges. A recurring issue is the risk of gentrification, where rising property values and rents displace long-standing communities and small businesses, eroding the socio-cultural fabric of heritage districts. Similarly, the commercialization of cultural spaces often prioritizes tourism and affluent audiences over local engagement, reducing authenticity and alienating original residents. This is particularly evident in the episodic vibrancy of many UAE heritage districts, which rely heavily on seasonal events for activation. Outside these periods, these spaces risk falling into dormancy, undermining their potential as year-round community-centred environments.

Temporality presents a significant challenge in the UAE, where the vibrancy of scheduled events often masks the inactivity of heritage spaces during off-peak periods. This dependence on programmed cultural activation highlights the need to reconceptualize heritage districts as continuously active, living environments. To address this, it is essential to redefine the relationship between heritage sites and their surrounding communities, ensuring that these districts remain vibrant and accessible beyond curated events.

Examples such as the Heart of Sharjah offer potential pathways forward. Its mixed-use planning model integrates residential, commercial, and cultural functions, transforming the district into a living ecosystem that balances tourism with sustained local engagement. Similarly, the adaptive reuse strategies employed in the MIZA Project demonstrate how historical infrastructure can be reimagined to meet contemporary cultural and economic needs. These projects exemplify how embedding everyday life into heritage districts can foster inclusivity, vibrancy, and resilience.

Moving forward, a stronger sense of shared ownership and community involvement is essential to the long-term success of the UAE's heritage strategies. Mitigating the risks of over-commercialization while prioritizing accessibility and inclusivity will be critical in preserving the cultural and historical significance of these spaces. Furthermore, the UAE must prioritize sustainability—not only in physical preservation but in fostering long-term cultural, social, and economic relevance. By grounding its heritage districts in both past and present, the UAE can ensure these spaces remain enduring symbols of its evolving identity.

The analysis of these challenges and opportunities is further broken down in Tables 1, 2, and 3, which highlight the key distinctions between the five UAE case studies in terms of public engagement, heritage processing, functionality, and their relation to new port developments.

Table 1. Key differences and challenges from cultural revitalization to gentrification.

	Cultural and economic benefits	Neutral impact/balanced effect	Risks and mitigations
Cultural revitalization	Events like the Sharjah Biennial foster creative energy, attracting global artists and audiences	Increased activity brings temporary vibrancy but may overshadow local heritage narratives	Focus on tourism can alienate residents, requiring initiatives like community-centred programming
Economic development	Boosts tourism and creative sectors, as seen in MIZA's adaptive reuse of warehouses for cultural industries	Economic growth benefits some sectors while leaving others, such as small businesses, struggling to compete	Rapid gentrification can displace original residents: mixed-use planning can help balance commercial and local needs
Preservation of heritage	Adaptive reuse balances historical preservation with modern functionality, as demonstrated by Al Shindagha Museum District	Some interventions maintain heritage integrity but may compromise accessibility or functionality for new uses	Over-commercialization risks commodifying heritage: sustainable tourism models are needed to prevent this
Community engagement	Cultural foundations, like SAF, offer workshops and events that involve the community in creative activities	Engagement can vary: programs may appeal to tourists more than locals, as seen in Al Jazeera Al Hamra's festivals	Alienation of local communities may arise if cultural spaces become exclusionary: participatory planning is essential
Gentrification	Revitalization enhances property values, improving infrastructure and services for the area, as seen in the Heart of Sharjah	Demographic shifts are gradual, with some displacement mitigated by efforts like locally driven-programming	Rapid gentrification risks displacing long-term residents and eroding the community: affordable housing policies and inclusive planning are needed
Authenticity	Enhances a district's unique identity by integrating modern creativity with historical elements, as seen in adaptive reuse at Al Shindagha	Authenticity is preserved in spaces like Al Jazeera Al Hamra but may feel diluted in others due to increased commercial activities	Over-commercialization risks erasing a district's original character: policies prioritizing local heritage and cultural continuity can counteract this
Accessibility	Revitalization improves public spaces and facilitates broader access to cultural events, as seen in Sharjah's mixed-use programming	Accessibility can vary: elite-focused programming in districts like MIZA attracts international audiences but risks alienating lower-income residents	Community-oriented programming can mitigate alienation and promote inclusivity, ensuring local populations benefit alongside tourists
Cultural sustainability	Long-term projects like SAF's residencies sustain cultural growth and heritage preservation by encouraging continuous engagement	Cultural sustainability may become seasonal or event-driven, as seen in episodic festivals like the RAK Fine Arts Festival	Short-term tourism initiatives risk commodifying culture: investing in community-driven programming ensures deeper engagement and continuity

Table 2. Key differences between the five case studies (part 1).

	Public engagement	Presentation of existing architecture	Occupancy patterns	Heritage processing	Cultural objectives	Proximity to port
Al Shindagha	Passive and tourist-driven	Static: focus on preserving historical elements	Permanent but diluted	Museumification	Education and tourism	Indirect: near historic creek
SAF Heart of Sharjah	Active and locally inclusive	Dynamic: a blend of conservation and contemporaneity	Occasional but concentrated	Performative reuse	Cultural revitalization through the arts	Indirect: historic trade route
Al Jazeera Al Hamra	Passive and reflective	Static: minimal intervention	Occasional and diluted	Museumification	Cultural revitalization and tourism	Direct: near the pearling harbour
Umm Al Quwain	Passive and limited	Permanent but diluted	Permanent but underutilized	Urban regeneration	Urban revitalization	Direct: neglected port
MIZA project	Active and focused on creatives	Dynamic: repurposed industrial design	Occasional and adaptive	Industrial heritage reuse	Fosters innovation and creative industries	Proximity to former warehouses

Table 3. Key differences between the five case studies (part 2).

	Public spaces	Connectedness to the rest of the city	Spatial interventions	Functional palette	Proximity to port	Community accessibility
Al Shindagha	Present and accessible	Connected: part of Dubai's creek network	Fixed: focused on preservation	Monofunctional: Museums and tourism services	Indirect: near the historic creek port	Primarily tourist-oriented, with limited local use
SAF Heart of Sharjah	Present and accessible	Connected: integrated into Sharjah's core	Adaptive and changing: supports events	Multifunctional: Cultural, educational, and artistic use	Indirect: historical trading routes	Strong local engagement via workshops and programs
Al Jazeera Al Hamra	Under construction	Remote and poorly integrated	Fixed: stabilization of heritage elements	Monofunctional: Reflective spaces and limited tourism	Direct: historic pearling harbour	Passive and reflective: limited active community engagement
Umm Al Quwain	Limited and under construction	Close but underdeveloped	Fixed: focused on reconstruction	Multifunctional: Museums, exhibitions, and cultural spaces	Direct: neglected modern port	Minimal community use, with occasional cultural events
MIZA project	Industrial spaces repurposed into accessible public venues	Remote but accessible	Ongoing: focuses on creative reuse	Multifunctional: Art studios, retail, and workshops	N/A: proximity to former port warehouses	Active creative community focus and limited broader accessibility

5. Conclusion

The UAE's approach to ports, heritage, and urban transformation reflects the complex balance between cultural preservation and economic modernization. Ports and their proximity in the UAE are not merely logistical or economic hubs; they serve as dynamic spaces where cultural, social, and spatial forces intersect. By positioning heritage as both a foundation for national identity and a catalyst for urban regeneration, the UAE demonstrates the potential to integrate its historical legacy with the demands of contemporary development.

Understanding ports and their proximities demands a multidisciplinary perspective that transcends the quantitative assessment of trade and infrastructure. Ports shape urban environments in profound and multifaceted ways, influencing cultural memory, social identities, and spatial dynamics. In the UAE, ports have evolved into multidimensional spaces where economic activity, cultural preservation, and urban growth converge. Addressing these complexities requires approaches informed by urban planning, architecture, cultural studies, and economics, reflecting the inherently interdisciplinary nature of port-urban interactions.

Unlike traditional port-city models that are gradually shaped in Europe or Asia, the UAE's approach is defined by oil revenues, centralized governance, and rapid modernization. The fast pace of this transformation reshaped coastal landscapes and produced urban heritage fragments that, while residual, carry significant cultural value. Current strategies aim to reverse and reshape these patterns, leveraging heritage and port proximities to craft new urban narratives. This dual process—reshaping and reverse shaping—highlights how ports and heritage have become critical to redefining the UAE's urban landscapes, offering both opportunities and challenges in fostering sustainable growth.

The ongoing construction and repurposing of smaller ports across the UAE and the Gulf region adds a competitive dimension to these transformations. Intensifying competition for trade, tourism, and cultural capital invites a rethinking of how ports influence urban spaces. Historical districts must remain central to these evolving strategies to preserve their cultural and spatial relevance. This raises broader questions: How will the expansion of smaller ports reshape Gulf cities and redefine regional dynamics? What role will they play in the geopolitical and economic landscape of the Gulf? These inquiries highlight the importance of exploring how port development fosters urban innovation, regional competitiveness, and cultural cohesion.

Nevertheless, the UAE's model is not without its challenges. The emphasis on fluidity and adaptability risks over-commercialization, gentrification, and reliance on episodic cultural activation. Many heritage districts face difficulties sustaining year-round engagement often depending on seasonal events and tourism-driven programming that may exclude local communities. Ensuring resilience in these spaces requires more than heritage preservation; it demands mixed-use planning, participatory development, and sustainable urban design that balances global aspirations with the needs of local populations.

The UAE's strategies illustrate that heritage is not static; it is an active driver of cultural vitality and urban vibrancy. However, they also provoke critical questions: Who benefits from these transformations? How can cultural integrity be preserved in the face of economic pressures? And how can heritage districts remain inclusive while competing for global recognition in cultural and economic spheres?

Ultimately, the UAE provides a compelling but context-specific model for reimagining ports and their proximities as integral components of urban futures. While not universally applicable, it offers valuable insights into the interplay of heritage preservation, urban regeneration, and economic development. By viewing ports as multidimensional spaces that extend beyond logistics to encompass cultural and social dimensions, scholars, policymakers, and planners can advance a deeper understanding of their transformative potential. This underscores the need for future research to explore these intersections critically, fostering innovative approaches to sustainable urbanization and regional competitiveness.

Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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Ocean and Society
2025 • Volume 2 • Article 9365
https://doi.org/10.17645/oas.9365

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Open Access Journal

A Data-Driven History of Gloucester's Fisheries Architecture

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Submitted: 4 October 2024 **Accepted:** 6 January 2025 **Published:** 26 February 2025

Issue: This article is part of the issue "Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions" edited by Mina Akhavan (TU Delft), Yvonne van Mil (TU Delft), and Carola Hein (TU Delft), fully open access at https://doi.org/10.17645/oas.i442

Abstract

This article presents the methods and preliminary results of research into the socio-ecological history of the Gloucester fisheries, with a focus on the interactions between humans and marine ecosystems. It explores how these interactions are reflected on land through the built environment and assesses the impact of human activity on marine life. The study is part of a broader research project examining the industrialization of fisheries along the North Atlantic coast. The objectives of this research are to establish a historical timeline of the Gloucester fisheries between 1880 and 1930, integrate statistical and geospatial data, and explore modalities for visualization and communication. Using a mixed-methods approach, the study is organized around five datasets that combine written, statistical, and geospatial evidence: Fishing Grounds, Fishing Fleets, Population Shifts, Industry Footprint, and Processing Plants. Although the results are still inconclusive, this research aims to lay the groundwork for an experimental methodology that will be further developed. The goal is to enhance historical analysis by introducing an environmental perspective, assessing the pressures on ecosystems, and grounding the analysis in quantitative statistical and geospatial data.

Keywords

digital humanities; environmental studies; fisheries; fishing architecture; marine ecosystems; urban history

1. Introduction

In Gloucester, Massachusetts, Atlantic cod fishing played a key role in shaping the urban landscape, with its iconic schooner fleet anchored at the inner port wharves and large areas dedicated to drying racks (Figure 1). Cod's dominance began to decline in the 19th century as shifts in market demand and advancements in fish processing and storage facilitated the rise of other species. Throughout its history, Gloucester has exemplified the close interconnection between urban development and fishing activities.

Figure 1. Drying fish, Gloucester, 1906. Source: Library of Congress (1906).

This article is part of a broader research project on the history of the North Atlantic, examining human–environment interactions through the development of the fishing industry. The research presented here centers on the case study of Gloucester and its fisheries, focusing on key species such as Atlantic cod (*Gadus morhua*), Atlantic halibut (*Hippoglossus hippoglossus*), haddock (*Melanogrammus aeglefinus*), mackerel (*Scomber scombrus*), herring (*Clupea harengus*), and menhaden (*Brevoortia tyrannus*).

The main research question driving this study is as follows: How do changes in the exploitation of marine resources correspond to transformations in the built environment? The study examines a 50-year period in Gloucester's history, from 1880 to 1930, and integrates this timeline with statistical and geospatial data analysis. This approach not only complements traditional historical analysis—since a single perspective is often insufficient to explain the complex relationship between humans and their ecosystems (Ojeda et al., 2022)—but also strengthens it by incorporating diverse sources and data types. Additionally, the study explores methods for visualizing and communicating data, shedding light on the historical connections between human activity and the marine environment.

The article outlines the methodology used in this ongoing research, detailing the procedures for data collection, processing, and analysis, as well as the types of evidence considered. To demonstrate the potential of the adopted strategy, preliminary results are presented and discussed, supported by a series of graphic materials. In doing so, the article highlights the contributions that a data-driven historical approach can offer, emphasizing the interoperability of the tools used to draw conclusions.

2. Historical Background

At the turn of the 20th century, New England's fisheries, including those in Gloucester, experienced significant changes. Until this time, fishing methods had remained largely consistent for centuries, relying on artisanal, small-scale approaches operated by family-owned and community-based fisherfolk (McKenzie, 2018). With the onset of industrialization, the fishing sector evolved, altering how fish were caught, processed, distributed, and sold (Murawski, 2005).

The selected time frame, from 1880 to 1930, highlights two significant milestones in regional fish landings and their environmental impacts. The first, in 1880, marks a peak in the cod fishery on Georges Bank, with 294 million pounds landed (Lear, 1998). The second, in 1930, records a milestone for the Massachusetts ground fishery, which landed 37 million haddock in Boston, while it is estimated that 70 to 90 million juvenile haddock were discarded at sea (Murawski, 1995).

During the 1800s, Gloucester became the largest fishing hub in the US, with its fleet reaching 352 schooners by 1889, surpassing cities like Boston (referenced in the Fishing Fleets dataset). This period saw the transition from sail-powered to engine-powered vessels, leading to significant changes in fishing methods and onshore operations. The adoption of otter trawlers introduced a new approach to marine resource extraction, resulting in notable impacts on fish stocks (Bolster, 2012).

Gloucester's population also grew significantly, peaking at 28,211 in 1895 (as shown in the Population Shifts dataset). The expansion of the fishing industry supported the development of businesses both directly and indirectly linked to fishing, further integrating the city's economy with its waterfront. A large share of the population was employed in fishing-related activities (mentioned in the Industry Footprint dataset).

Another key development during this time was the shift from salted to fresh fish, enabled by advances in filleting and quick-freezing technology (Lear, 1998). This shift impacted the urban landscape and influenced the configuration of processing facilities (as seen in the Processing Plants dataset).

2.1. A Multispecies Perspective

For over four hundred years, Gloucester has been both economically and culturally linked to groundfishing (Murawski, 1995). Although cod has historically been the most significant species, driving the development of Gloucester's fishing industry and often highlighted in literature, such as Rudyard Kipling's (1897) *Captains Courageous*, the reality of this history is characterized by a diverse array of species.

Around the mid-19th century, mackerel emerged alongside cod as a major food fish and eventually surpassed it in catch volume. By the latter part of the century, previously overlooked species like halibut, herring, haddock, and various shellfish also rose in popularity in the marketplace (Johnston, 1984).

This transition to new fish species is closely related to the methods of fish processing and preservation, especially with the introduction of icing in the 1840s and the installation of ice houses on vessels. Previously, most fish in New England were salted at the time of capture, then washed and dried on fish flakes after being landed. Depending on the species and market, they could also be smoked or pickled in brine. The first

experiments with canning began in the 1840s, but it wasn't until the 1870s that it became established, particularly for herring and mackerel (Johnston, 1984).

With the growing demand for fresh fish in the Boston market—the most important market in New England—species that had previously been less targeted gained relevance and began to be intensively fished. One such case is halibut, previously regarded as a trash fish (Johnston, 1984).

Before the introduction of ice in this fishery, unsold halibut was preserved using traditional methods such as salting, smoking, or drying. However, owing to the species' large, irregular size and variable body thickness, these methods were less effective at maintaining its quality, making halibut less desirable for commercial marketing. The growing demand for fresh fish led to a significant increase in halibut fishing by 1852, with distribution expanding rapidly across the eastern US and into the eastern Canadian provinces. The market for iced halibut was particularly aimed at middle- and upper-class consumers in US society (Vose, 2010).

In response to the growing demand from Boston for fresh halibut, a handline fishery was established on Georges Bank. By 1848, seasonal landings of halibut ranged from 845–1,625 tons. However, by 1850, the fishery had become unprofitable, prompting fishers to shift their efforts to Seal Island Bank, Brown's Bank, and Sable Island Bank. By the 1870s, the Gloucester fleet was primarily operating in deeper waters, employing two-masted schooners, each outfitted with six dories. Fishing was conducted using longlines, with each line holding 350 to 380 hooks. Bait included herring, mackerel, menhaden, cod, haddock, hake, and even birds. In 1878, approximately 4,842 tons of fresh or iced halibut were landed in Gloucester (Cushing, 1988).

This is an example of the adaptability of the Gloucester fisheries, responding on the one hand to market demands and, on the other, to environmental conditions and the state of fish populations, which required them to move to increasingly distant fishing grounds, thus increasing the risks for the fisherfolk. As Vose (2010) notes, the halibut fishery had the highest mortality rate, with the famous story of Howard Blackburn serving as a notable example (McKenzie, 2018).

2.2. A Multisectoral Perspective

While great fleets of vessels sailed to fishing banks, such as the Grand Banks of Newfoundland, a multitude of shore-side businesses operated in downtown Gloucester to support the fishing industry. These included sail lofts, spar sheds, ice houses, chandleries, cooperages, blacksmith shops, and foghorn makers (Murawski, 1995).

The transition from sailing vessels to engine-powered vessels had significant consequences not only for the exploitation of marine resources but also for the businesses associated with navigation, the built environment, and the local material culture. This transition profoundly transformed Gloucester's urban landscape (Kurlansky, 2010). However, just as fisherfolk continually adapted to shifts in target species and fishing grounds, the city also adapted.

As the industry expanded, innovative uses for surplus fish and by-products emerged, significantly reducing waste. Fish heads, tails, and bones were processed into fish meals, which served as both fertilizer and animal feed. Skins of dried cod and cusk were transformed into glue, while swim bladders were utilized to produce isinglass, an essential clarifying agent in beer and wine production (Vose, 2010).

Fishing companies themselves were highly diversified. One example is the menhaden fisheries, a fish that, prior to 1855, had little commercial value, being used mainly as bait, with some barrels salted and shipped to the West Indies, and widely applied as fertilizer in coastal fields (Goode, 1880). In 1875, a new industry emerged, using menhaden for oil production. As a source of oil, menhaden became the most important marine species, surpassing whale, seal, and cod oil production in America. By 1876, the yield of the menhaden fishery was more than twice that of any other fishery in the US. In terms of product value, it was surpassed only by the cod and mackerel fisheries (Goode, 1880).

2.3. A Multiscale Perspective

The history of Gloucester's fisheries is deeply intertwined with regional networks and dependencies, encompassing both land-based and maritime aspects. Several initial factors, such as its proximity to the rich fishing grounds of the Gulf of Maine and major market hubs like Boston, played a crucial role in Gloucester's development. The opening of a major fish pier in Boston in 1914 modernized docking facilities and the marketplace, streamlining the distribution of fresh fish (Johnston, 1984). Similarly, Gloucester's closeness to Essex, a significant center for fishing vessel construction, fostered strong business ties between fisherfolk and boat builders.

The subsequent expansion of Gloucester's fishing industry was driven by the growth of these networks, as noted by Vose (2010). Four key technological advancements were instrumental in enabling the long-distance distribution of perishable goods: the railroad, faster vessels, preserved ice, and the telegraph.

By 1880, the state of New England supplied about one-third of the nation's total fish output, with the remaining supply coming from the southern Atlantic and Pacific Northwest regions (Johnston, 1984). The efficient distribution of Gloucester's fish relied on a network of cities, which was greatly enhanced by the development of railroads in the late 19th and early 20th centuries. Work on extending a steam-powered rail service from New York to Boston began in 1837, and by 1847 Gloucester was connected to this network. This rail infrastructure opened new markets in cities like New York, Philadelphia, Chicago, and Montreal (Vose, 2010).

Maritime advancements were equally vital. One of the most significant developments was the introduction of engines to the fishing fleet—first steam, then gasoline, and eventually diesel. Initially added to schooners as auxiliary power, these engines significantly extended the vessels' range and allowed for faster trips to and from the fishing grounds (Johnston, 1984). Another important factor was the emergence of trawlers (Murawski, 2005). These two developments were fundamental in expanding and intensifying the offshore sector of the fishing industry (Johnston, 1984).

Improvements in cold storage, marketing, and distribution also transformed the industry, making it possible to deliver fresh fish to areas far from the coast. The development of fish filleting techniques, along with effective methods for freezing and storing fish, allowed Americans in inland regions access to fresh seafood for the first time (Murawski, 1995).

The invention of the telegraph also played a pivotal role in Gloucester's fishing industry. Telegraph services, along with transatlantic cable, enabled distant fleets to receive market price updates and storm warnings

(Kurlansky, 2011). Before the telegraph, vessels returning from offshore trips often had to sail between ports such as Gloucester, Boston, or New York, searching for the best market price for their catch—an inefficient and time-consuming procedure given the perishable nature of the goods. With the telegraph, this process became far more efficient, eliminating the need for such time-consuming detours (Vose, 2010).

3. Sources and Methods

This research is a data-driven historical analysis, incorporating both quantitative and qualitative data, thus following the principles of mixed methods research (Feilzer, 2010; Tashakkori & Creswell, 2007). The aim is to enhance historical analysis by incorporating multiple approaches, drawing on different sources of evidence, analytical methods, and data types.

From a methodological standpoint, the first phase of this study was exploratory. It examined the available sources for the period under consideration (between 1880 and 1930) with a focus on systematically organizing data that would enable the identification of trends and changes during this period, as well as how to digitize, process, analyze, and correlate this data.

Regarding sources, the research conducted thus far has relied on digital archives, where primary and secondary materials have been collected and analyzed. The primary digital archives used include Digital Commonwealth, the Fitz Henry Lane Archive, the Library of Congress, the US National Archives and Records Administration, the New York Public Library, and the Cape Ann Museum. Additionally, the digital collections of the City of Gloucester Archive and Sawyer Free Library provide important historical records from the period under analysis.

The archival materials are divided into four types of data: written records, statistical data, geospatial data, and visual data. For written data, since these are digitized publications, no transcription was necessary, and Atlas.ti was used for thematic analysis. For statistical data, despite being part of digitized publications, the processing required a lengthy transcription into Excel for subsequent statistical analysis and visualization using PowerBI. For geospatial data, particularly historical maps and nautical charts, the process involved considerable time in adjusting the base materials, followed by georeferencing using QGIS. Visual data, particularly architectural drawings, were digitized using AutoCAD to produce vectorized and scaled drawings.

As will be detailed in the results section, a central procedure of the analysis is correlating these different data types to enhance the insights derived from them. Moreover, processing historical data with digital tools enables the generation of new information not present in the original sources. One example of this is the integration of statistical and geospatial data. This process of merging different data types for analysis requires the use of multiple software tools, with the integration of Excel and QGIS being central to this research.

4. Results

4.1. Fishing Grounds

The objective of this dataset is to identify and map fishing pressure—i.e., the intensity of fishing activities in a given area (Stewart et al., 2010)—with a focus on the fishing grounds utilized by New England's fishing fleet.

The source for this dataset is a publication by Walter H. Rich from 1929, which includes historical nautical charts and statistical data on fisheries in the Gulf of Maine. The 1929 data is detailed, specifying captured species, their weight and value, fishing areas, fishing trips conducted, and the port of landing, namely Gloucester, Boston, or Portland. Statistical data from 1916 to 1929 is also presented, but it is less detailed, providing only total catches, their value, and the port of landing.

Statistical data from the *Report of the Commissioner* (US Commission of Fish and Fisheries, 1894–1929) was also considered. Similar to the data presented by Rich, this covers a longer period, allowing us to expand the analysis. However, there are large amounts of data still being processed.

This dataset involved a two-step process because of the different types of evidence. Nautical charts were first georeferenced using QGIS and then digitized, focusing primarily on the fishing grounds. Concurrently, the statistical data was digitized into Excel and linked to the geospatial file, assigning information to vectorized objects. This included naming the fishing grounds, specifying the species present in each, and detailing seabed types. Additionally, statistical data on catches were matched with each port.

The combination of geospatial data related to the fishing grounds and its integration with fishing statistics from various years within the period under analysis allows us, in the initial phase, to identify the marine territory that encompasses Gloucester and its fishing grounds, based on the targeted species and seabed types (Figure 2).

The GIS file also enables us to extract information not mentioned in the sources such as the linear distance from Gloucester's port to specific fishing spots, to calculate the area assigned to fishing grounds in nautical

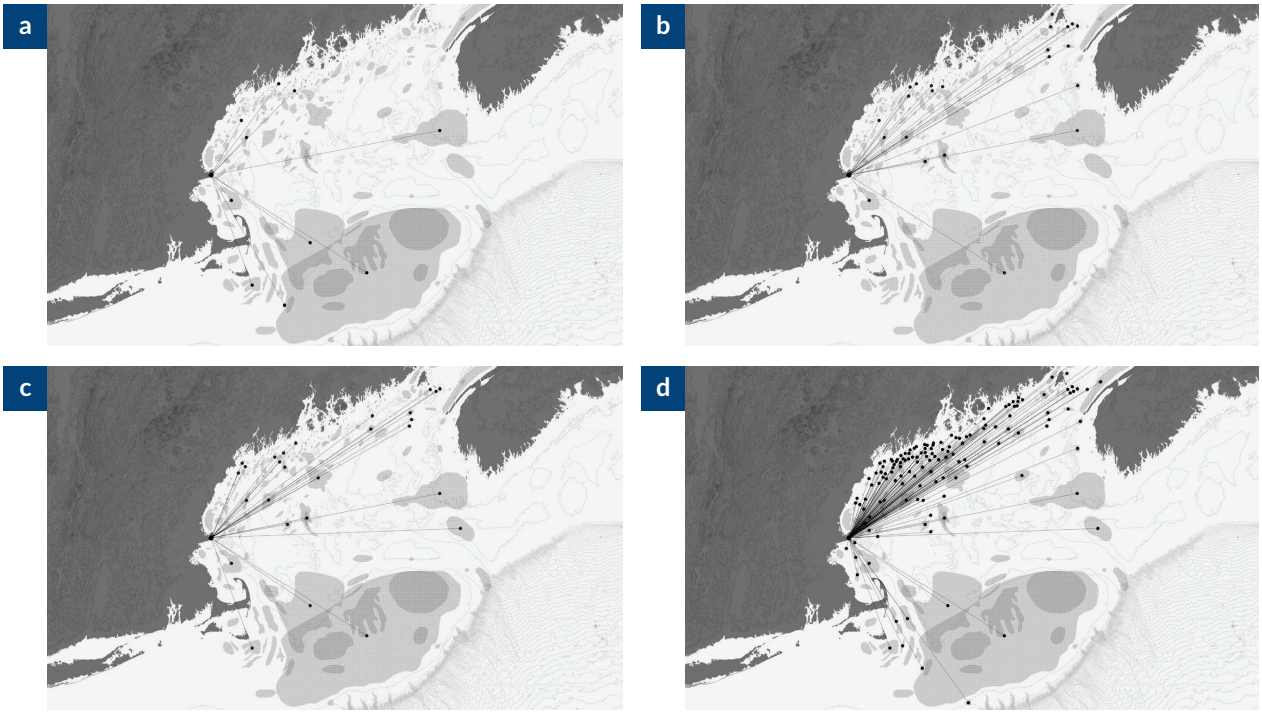

Figure 2. Distribution of fishing grounds by species. Notes: (a) Mackerel (*Scomber scombrus*); (b) Herring (*Clupea harengus*); (c) Atlantic halibut (*Hippoglossus hippoglossus*); (d) Atlantic cod (*Gadus morhua*). Note: This figure is adapted from the data in Rich (1929).

charts, or to derive bathymetric information. Additionally, it allows us to map fishing pressure based on the species captured in each fishing ground and observe how this changed year by year. For instance, as seen in Figure 3, in the Georges Bank group in 1929, haddock far surpassed cod catches a species that historically had greater significance in this same bank (Lear, 1998).

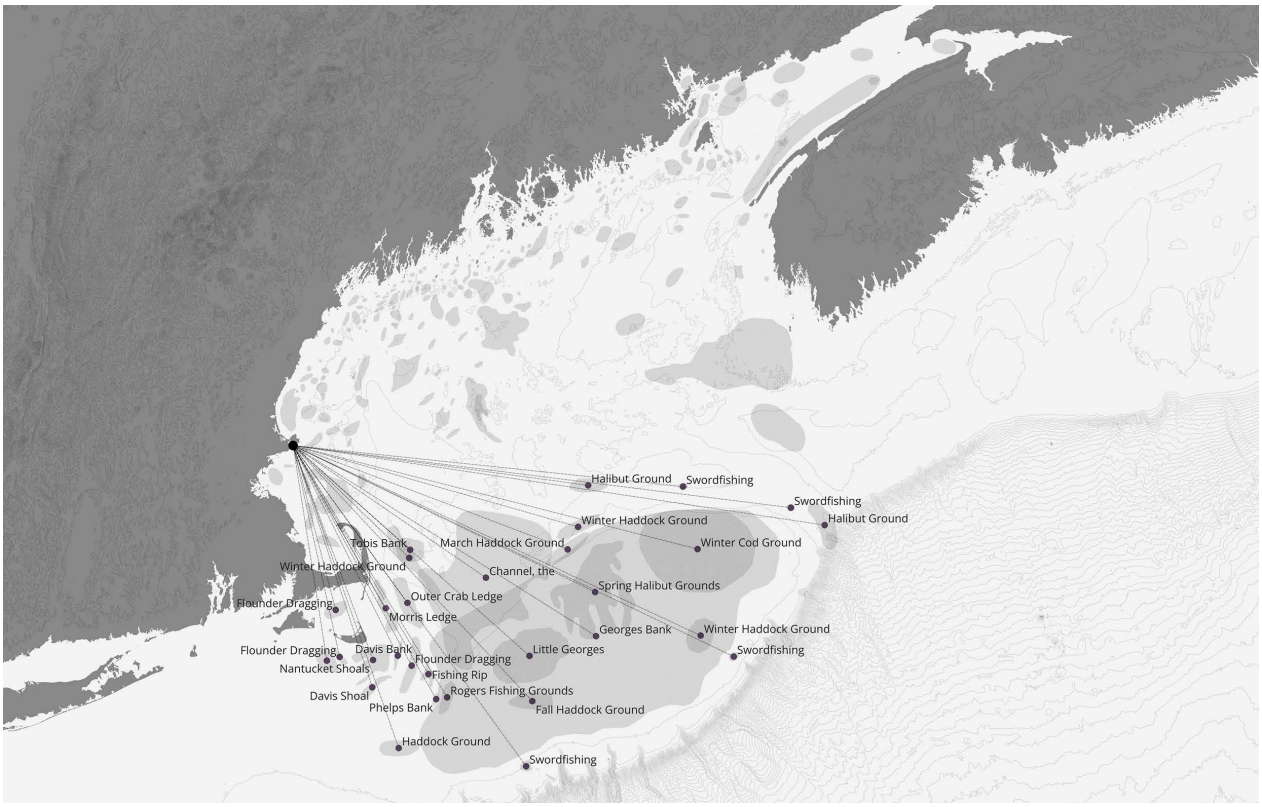

Figure 3. Selection of data from Georges Bank in 1929. Notes: In that year, fishing vessels from Gloucester made 3,499 trips to Georges Bank, with an additional 793 trips by otter trawlers, totaling 4,292 trips; the top three landed species were haddock (180,858,105 pounds), cod (41,471,219 pounds), and mackerel (9,652,991 pounds); the total landings from Georges Bank for the year amounted to 243,425,767 pounds. Note: This figure is adapted from the data in Rich (1929).

The next step will involve following the same procedure with another source (Goode, 1887), which maps fishing grounds outside the Gulf of Maine, such as Brown's Bank, Sable Island, Banquereau, and the Grand Banks of Newfoundland. On the other hand, continuing to process and analyze the statistical data will provide us with insights into the itinerancy of Gloucester's fleet, as well as the changes and trends in species and landing volumes for each fishing ground.

4.2. Fishing Fleets

The objective of this dataset is to characterize Gloucester's fishing fleet in comparison to other major American ports and to analyze how it changed.

Two sets of sources were used to compile this dataset. The first set consists of regular publications listing registered vessels in Gloucester and other American ports for the years 1870, 1880, 1889, 1900, and 1908. The second set comes from a publication titled *Fishermen of the Atlantic*, covering the years 1910 and 1920.

Both sources provide similar types of data, including vessel names, types, tonnage, construction locations, construction dates, and owners or companies. Data on vessel dimensions, such as length, breadth, and depth, began to appear in 1891 but was not included in this analysis.

As the data originated from publications, the first step was to digitize it into an Excel spreadsheet. The data was then standardized to address inconsistencies, such as different terms for the same types of vessels or variations in the naming of construction locations. Data iteration and analysis were performed using Power BI. Given that some of the data is geospatial, such as the port of registration and construction locations, it was also imported into QGIS for territorial distribution analysis.

The data reveals that Gloucester had the largest fishing fleet, surpassing even Boston's. For example, in 1900, Gloucester had a total of 309 vessels, compared to Boston's 54. Although this gap narrowed in subsequent years, Gloucester still had 180 vessels compared to Boston's 100 in 1920. Additionally, the number of sailing vessels in Gloucester decreased from a peak of 428 in 1870 to next to nothing by 1920 ($n = 7$), as they were replaced by engine-powered vessels (Figure 4). In 1910, screw vessels appeared in the data for the first time in Gloucester ($n = 45$), and their numbers more than doubled by 1920 ($n = 107$; Figure 5).

It is also noteworthy that a significant portion of Gloucester's fleet was built in Essex. Among the total vessels built during the period under analysis, Essex ranks first ($n = 1{,}188$), followed by Gloucester ($n = 386$), and then 104 other American towns ($n = 587$). This highlights the importance of the regional network in supporting the production of Gloucester's fishing fleet. Finally, the dataset reveals a trend of reduction and concentration in vessel ownership. The number of companies decreased from 54 in 1870, each owning an

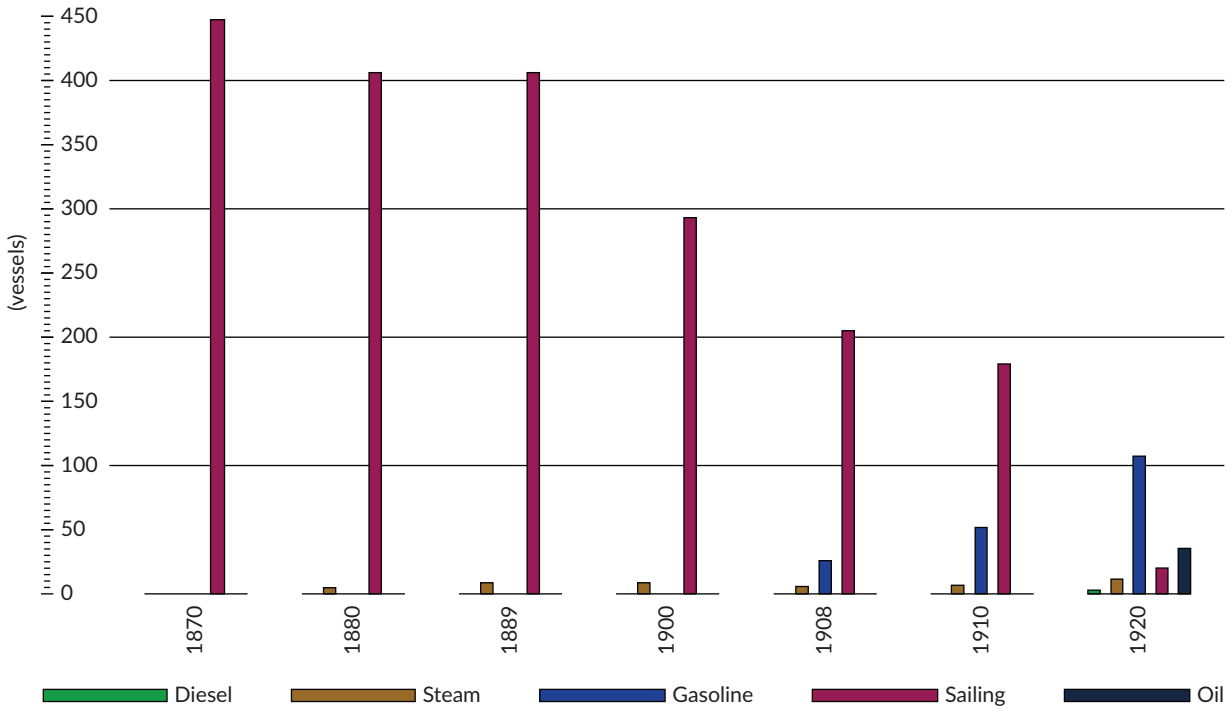

Figure 4. Different types of propulsion of fishing vessels registered at the port of Gloucester. Note: This figure is adapted from data in the *List of Vessels Belonging to the District of Gloucester* (Sawyer Free Library, 1869–1908) and *Fishermen of the Atlantic* (Fishing Masters' Association, 1910, 1920).

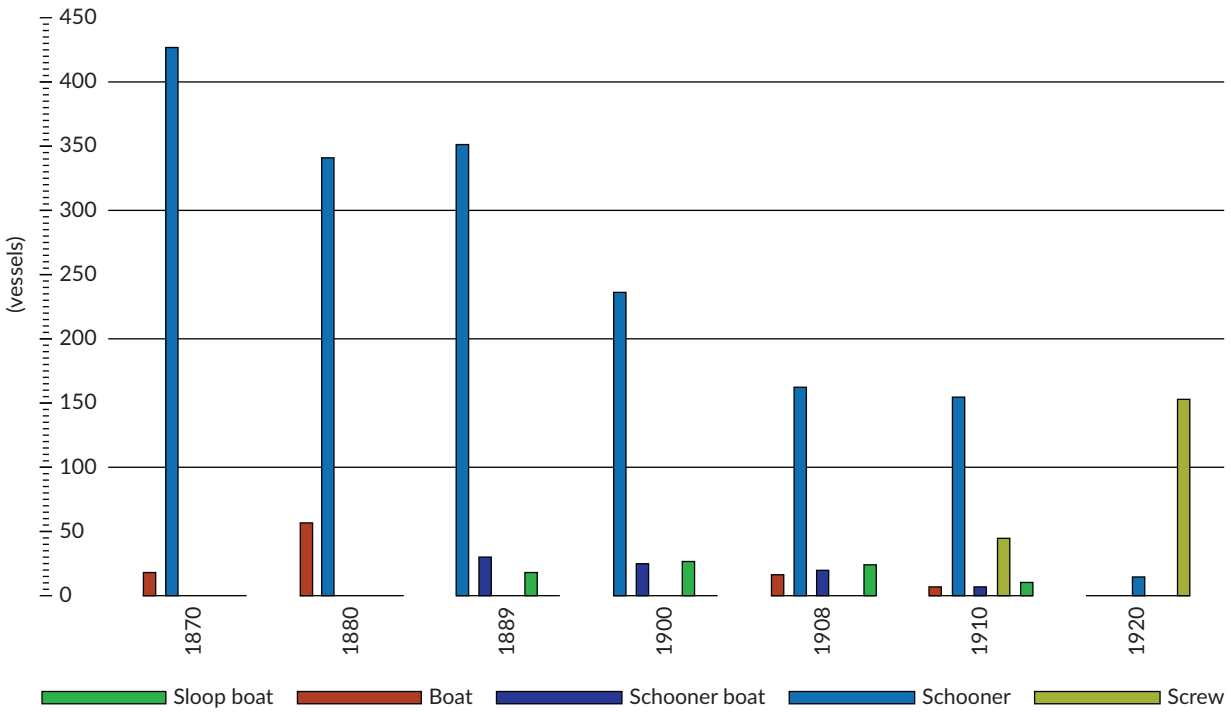

Figure 5. Different types of fishing vessels registered at the port of Gloucester. Note: This figure is adapted from data in the *List of Vessels Belonging to the District of Gloucester* (Sawyer Free Library, 1869–1908) and *Fishermen of the Atlantic* (Fishing Masters' Association, 1910, 1920).

average of seven vessels, to 13 companies in 1920. The Gorton-Pew Vessels Co. emerged as the largest in 1920, owning 43 vessels compared to an average of three vessels per company.

4.3. Population Shifts

This dataset aims to understand the population transformations in Gloucester in comparison to other New England cities, in order to establish a relationship between the development of fisheries and demographic fluctuations.

Two sources were used for collecting this population data: eight volumes of the *Gloucester City Directories*, from each decade between 1860 and 1930, and four volumes of the *Decennial Census*, from 1960 to 1990. The data collected for this dataset are limited to the population sizes of a group of American towns, including Gloucester, Beverly, Essex, Manchester, Marblehead, Salem, Boston, and Provincetown, at five-year intervals within the time period analyzed.

The sources used are historical publications and thus needed to be digitized into an Excel spreadsheet. In this case, automatic text recognition was effective, facilitating the digitization process. The data was double-checked, and since the volumes frequently reference previous years, cross-referencing was conducted to detect errors.

In 1900, Gloucester had a population of 21,161 while Boston had 560,892. In 1930, Gloucester's population was matched by Beverly ($n = 24{,}204$), which then surpassed Gloucester. One notable aspect is that Gloucester

experienced a population peak in 1895 (n = 28,211), after which the population stabilized for nearly a century, only reaching this number again in 1990 (Figure 6).

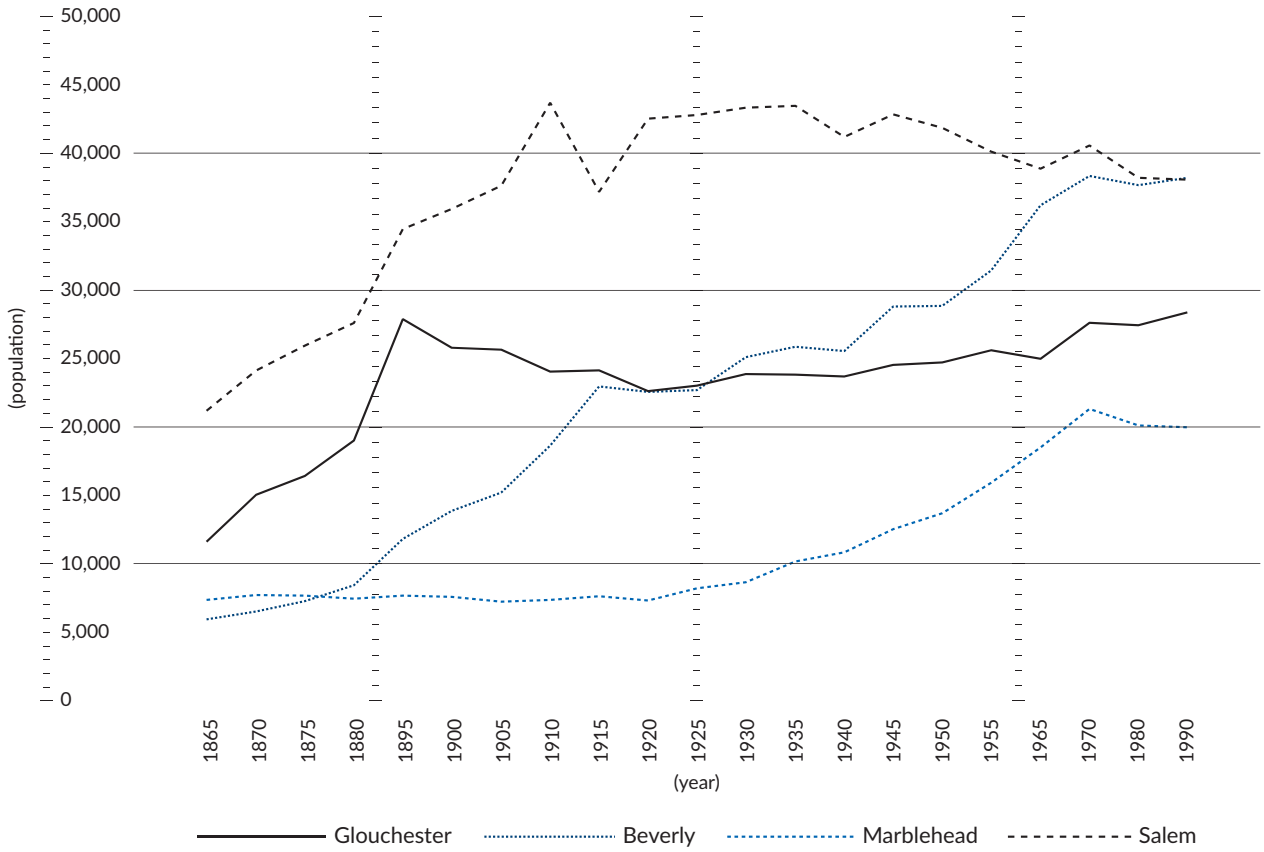

Figure 6. Demographic evolution of Gloucester and other neighboring cities. Note: This figure is adapted from data in the *Gloucester City Directories* (Sawyer Free Library, 1860–1930) and the *Decennial Census by Decade* (United States Census Bureau, 1960–1990).

4.4. Industrial Footprint

The objective of this dataset is to determine the footprint of the fisheries sector in the city of Gloucester, focusing on both fishing companies and employment.

The sources for this dataset include the *Gloucester City Directories* (Sawyer Free Library, 1860–1930), as used in the previous dataset, with a focus on the type of company and its registered name and address. Additionally, data was collected on Gloucester residents, including their names, professions, and addresses. Another source consists of a series of maps of the city produced by the Sanborn Map Company (1888–1949), along with two maps from the *Atlas of the City of Gloucester* (Geo. W. Stadly, 1899; Hopkins, 1884).

This is an ongoing dataset, and, so far, only the data from 1900 has been processed. The work process involved two main stages. The first stage was the digitization and processing of the city directory data. Since the data is in the form of scanned books, the digitization process is quite time-consuming. Additionally, some of the streets listed as addresses no longer exist—such as Vincent Street and Wharf Street—so all entries had to be manually inserted using the 1899 base map in GIS to extract coordinates. In the case of occupations, there

are 10,084 entries and for companies, there are 1,661 entries. The second procedure involved georeferencing the maps from the Atlas of the City of Gloucester using QGIS, followed by their digitization.

The cross-referencing of the 1900 city directory data with the 1899 historical maps makes it possible to visualize the industrial footprint in Gloucester at that time (Figure 7). From the perspective of the companies, we see that they are mainly located in the western part of the city. If we create a top-five list of streets most occupied by fisheries companies, Main Street ranks first (n = 60), followed by Commercial Street (n = 27), Duncan Street (n = 20), and Parker Street and Rogers Street (both n = 13).

From the perspective of fisheries-related employment, there is an even distribution across the city, except for two major areas to the west: one in the older central district and another near the beach. If we compile a top-five list of streets most occupied by fisheries-related workers, Main Street again ranks first (n = 298), followed by Friend Street (n = 161), Duncan Street (n = 112), Commercial Street (n = 76), and Locust Street (n = 70). Additionally, processing this data reveals the great diversity and number of businesses related to fisheries. It also reveals economic trends, such as the significative presence of Salt Fish Dealers (n = 55) compared to Fresh Fish Dealers (n = 9).

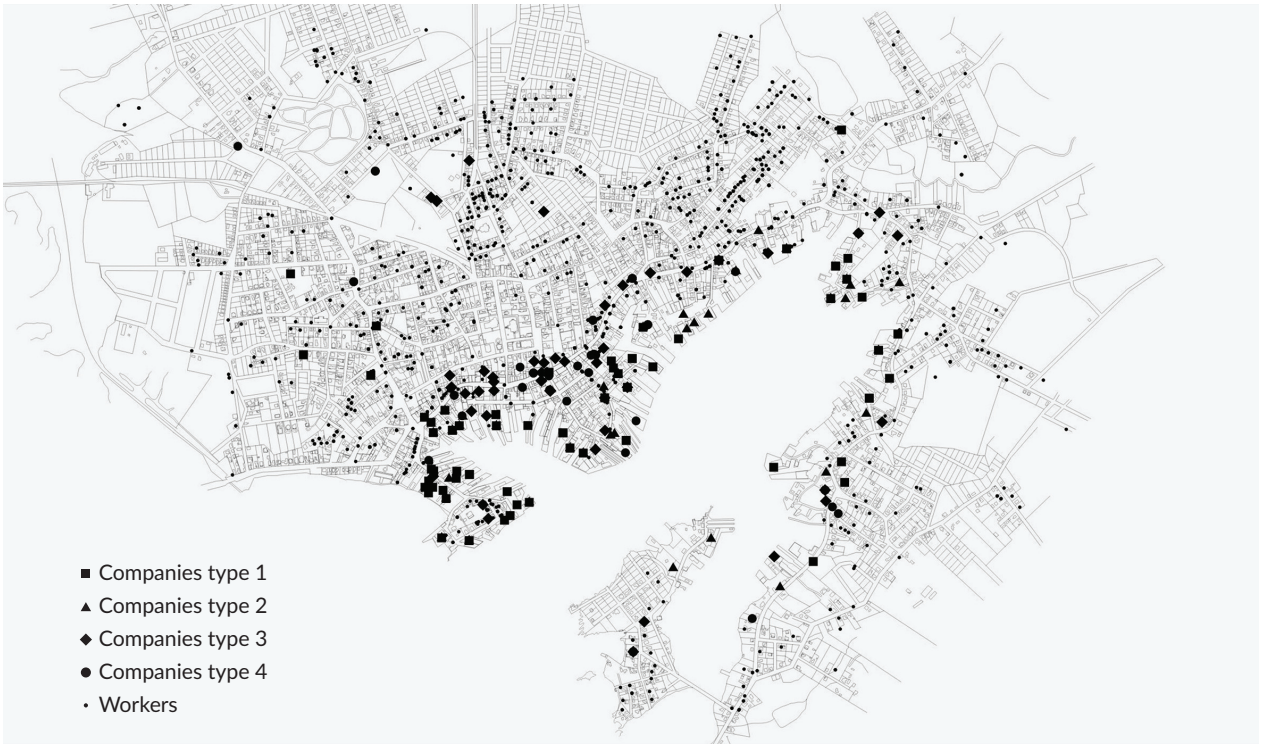

Figure 7. Mapping of companies and workers connected to the fishing industry in Gloucester in 1900. Notes: The companies were organized by type, based on how directly they were involved in fishing; type 1 includes fish dealers for fresh and salted fish; type 2 includes companies that process fish, such as fish criers, fish oil producers, and smokers and curers of fish; type 3 includes companies that produce equipment for the fishing sector, such as fisherfolk's outfits, fishing lines, rope and cordage, and bait and stop nets; type 4 includes companies related to shipbuilding in general, such as ship carpenters, boat builders, and ship chandlers; this figure is adapted from data in the *Gloucester City Directories* (Sawyer Free Library, 1860–1930) and the *Atlas of the City of Gloucester* (Geo. W. Stadly, 1899).

4.5. Processing Plants

The objective of this dataset is to trace the morphological development of a set of processing plants and their respective wharves.

The sources are divided into two types: historical cartography, primarily maps produced by the Sanborn Map Company (1888–1949) and two maps from the *Atlas of the City of Gloucester* (Geo. W. Stadly, 1899; Hopkins, 1884); and visual evidence, such as historical photographs or depictions of processing plants, which were often used as company emblems and appeared as headers on official documents.

This dataset is still in its early stages. As with other datasets, the maps were georeferenced using QGIS for digitization. In this particular case, where morphological analysis is carried out through a direct comparison of the built configurations of the processing plants over time, digitization is crucial in more effectively relating different cases and mapping their transformations.

A set of companies was identified and analyzed, including Cunningham & Thompson, David B. Smith & Co., John F. Wonson & Co., John Pew & Son, Sylvanus Smith & Co., Slade Gorton, and Shute & Merchant, as the most significant in Gloucester before the formation of Gorton-Pew Fisheries Co. in 1906.

We provide the example of John Pew & Son (Figure 8). These four phases exemplify the transformation these structures underwent, which became particularly evident in the cartography from 1898 onward. In just 11 years, we observed a significant increase in the built area, particularly with the construction of a large, covered space that had previously been used for drying fish. This transformation is especially clear

Figure 8. Evolution of the John Pew & Son processing plant. Notes: (a) 1892; (b) 1898; (c) 1903; (d) 1919; this figure is adapted from data in the *Collection Sanborn Maps* (Sanborn Map Company, 1888–1949).

when cross-referenced with visual evidence, which shows how the external area functioned with drying racks and how its mass plan changed after its conversion into processing facilities (Figure 9).

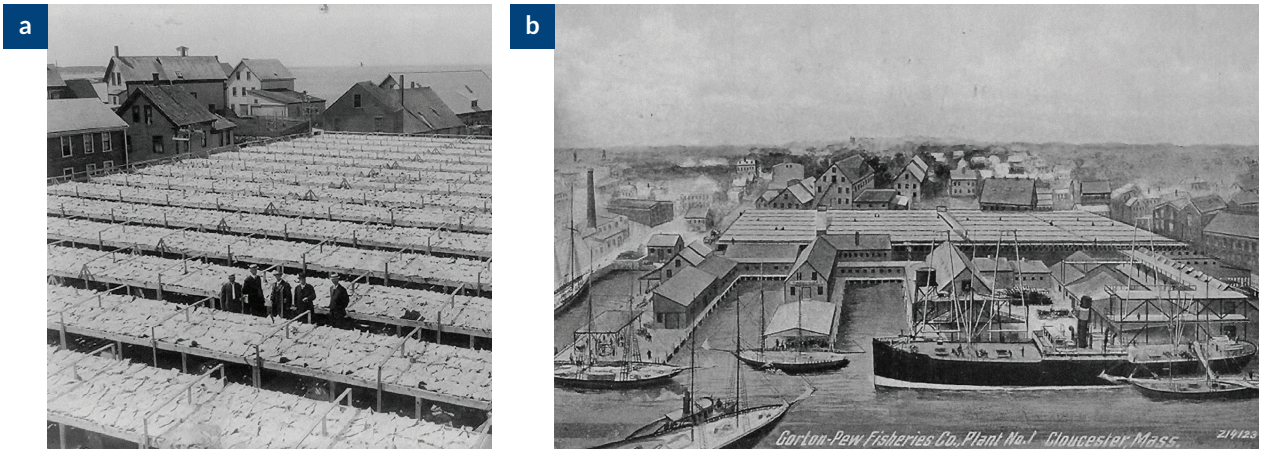

Figure 9. Evolution of the John Pew & Son processing plant. Notes: (a) John Pew & Son's Cod Flake Yard, 1899; (b) Gorton-Pew Fisheries' processing plant, 1923; this figure is adapted from data in the Library of Congress (1899, 1923).

5. Discussion

5.1. Gloucester's Fisheries

The period under analysis covers Gloucester's peak as the leading fishing power in the US and is characterized by a rich array of historical records. These records range from statistical data on fishing (Rich, 1929; US Commission of Fish and Fisheries, 1894–1929) and scientific research related to fisheries and species biology (Goode, 1887) to detailed information about Gloucester's fleet, including regular publications such as the *List of Vessels Belonging to the District of Gloucester* (Sawyer Free Library, 1869–1908). It also includes information about the companies and workers involved in the fishing industry, particularly the Gloucester Directory series from 1860 to 1930. A particularly valuable aspect is the cartographic evidence, which includes highly detailed surveys produced at short intervals, providing representations of the city at nearly decade-long intervals, especially the series produced by Sanborn Map Company from 1888 to 1949.

In a study relying on data-driven historical analysis, the availability of such extensive and consistent records is crucial in enabling meaningful conclusions to be drawn. On the one hand, the sheer volume of existing data is a key asset; on the other, the systematic nature and uniformity of this data over a defined period allow for the identification of patterns, trends, peaks, and changes. This has facilitated the establishment of five datasets—some already complete in terms of data collection and processing, while others are still under development. The diverse range of data from various types and sources is a deliberate strategy, allowing these datasets to be cross-referenced with the literature so that more robust insights can be generated and correlations identified.

From a literature perspective, extensive research has examined the history of fishing in New England, with Gloucester playing a key role (Cushing, 1988; Johnston, 1984; Lear, 1998; McKenzie, 2018) and the relationship between fisheries history and ecosystems (Bolster, 2008, 2012). Studies have also focused on key species such as Atlantic cod (Dybas, 2006; Kurlansky, 2010, 2011) and menhaden (Frye, 1978; Goode,

1880), as well as on broader multispecies analyses (Sutcliffe et al., 1977). However, the historical connection between fisheries and urban and architectural development remains underexplored.

This is significant because, in many coastal communities with economies essentially based on fisheries, the built environment reflects the fish–human relationship (Thurstan, 2022). One of the aims of this study is to explore this connection by examining how marine resource extraction has shaped the city's built environment, starting with changes to the coastline and wharves, the development of industrial and port areas, and the types of structures supporting fishing and fish processing, which have historically played a significant role.

From a methodological perspective, although they focus on different study objects and objectives, various inter and multidisciplinary studies in the fields of history and environmental history have utilized statistical data (Hayes et al., 2024; Holm et al., 2024), as well as statistical and geospatial data (Thurstan et al., 2024; Zu Ermgassen et al., 2024), highlighting the operational potential of these approaches.

5.2. A Data-Driven Historical Analysis

The preliminary results we present underscore the potential of combining historical analysis with statistical and geospatial data, not only to deepen and clarify existing knowledge but also to uncover new insights that were previously hidden. By complementing the literature, the combination of these methods enables us to refine and expand on themes already explored by previous studies.

For example, data-driven analysis allows for the quantification and verification of historical transitions, such as the characterization of Gloucester's fishing fleet over the period under analysis. In the Fishing Fleets dataset, we observe that, in general terms, the fishing fleet decreased from 409 vessels in 1880 to 180 in 1920. If we focus on schooners, the principal type of vessel in the late 19th and early 20th centuries (Vose, 2010), we see a drop from 342 schooners in 1880 to just 15 in 1920, with gasoline screws increasing to 107 by 1920. On the other hand, in the Population Shifts dataset, we observe a similar downward trend, with the population peaking in 1895 ($n = 28{,}221$).

The decline in both the fleet and the resident population may suggest Gloucester's waning status as a fishing power (Johnston, 1984) or, alternatively, that vessels and fishing methods became more efficient. According to Cushing (1988), pre-industrial fisheries required a large number of fisherfolk to achieve relatively small catches, a situation that was reversed with industrialization. This is an aspect that can be further analyzed by cross-referencing these datasets with catch statistics from the Fishing Grounds dataset, which is still under development. These transitions, often described in qualitative terms, gain new depth when supported by statistical evidence.

Another key aspect of this period, derived from the Fishing Grounds dataset, is the transition from salt to fresh fish. The data shows that in 1895, salted cod landed in Gloucester amounted to 43,227,963 pounds, compared to 4,105,526 pounds of fresh cod. Despite this large difference, these figures had evened out by 1914, with 14,743,280 pounds of both salted and fresh cod landed. With trends running in opposite directions, fresh cod would soon surpass salted cod. By 1919, fresh cod landed in Gloucester totaled 27,263,118 pounds, compared to just 4,722,851 pounds of salted cod.

As Lear (1998) notes, this transformation in the fishing sector was made possible by two technologies, both originating in New England: filleting and quick freezing. Filleting at source drastically reduced transportation costs per unit of edible product, while allowing waste materials to be converted into valuable by-products. This revolutionized the way fish products were packaged and handled, enabling brand differentiation and creating new opportunities for visual appeal and marketing. Quick freezing, in turn, transformed the industry by ensuring consistent quality and significantly improving the shelf life and portability of perishable goods over time and distance. It not only helped smooth out supply fluctuations but also opened new and far-reaching markets.

This shift from dried to fresh fish is also reflected in the Processing Plants dataset, where we see how large areas for fish flakes were replaced by facilities for storage and processing. The construction of the Gloucester State Fish Pier in 1937 (Figure 10) marked a pivotal moment of this change, as the city sought to assert its autonomy in relation to the Boston market, which had previously dominated the fresh fish trade.

At the same time, this methodology offers new insights by revealing relationships that were previously unseen. The spatialization of data, for instance, not only helps map the geographic spread of Gloucester's fishing grounds but also exposes the extent of the region's integration into broader national and international networks. These networks, which involved both the production of ships and the trade of

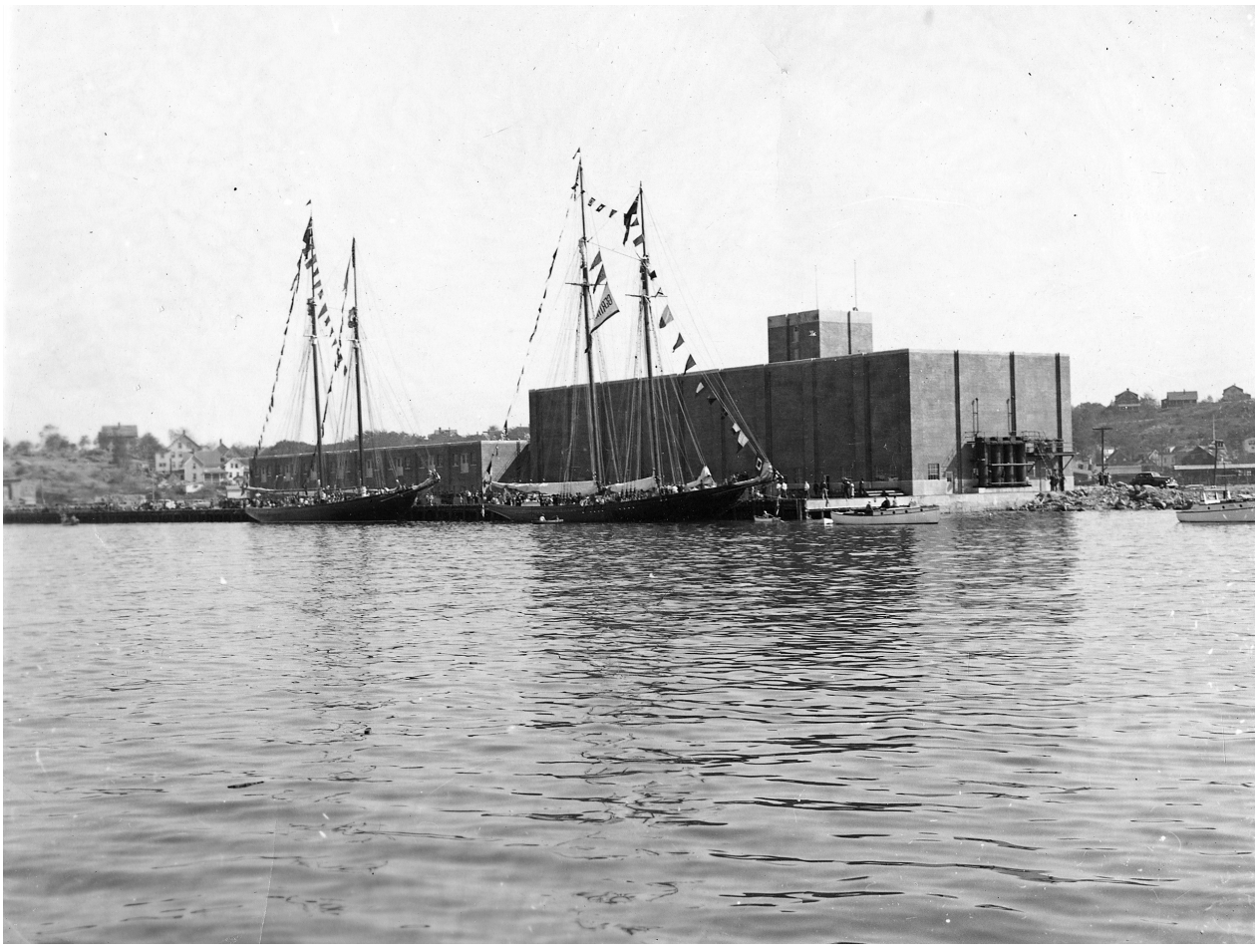

Figure 10. Gloucester State Fish Pier, 1939. Source: Curtis (1939).

marine resources, illustrate the large-scale nature of Gloucester's fishing industry, suggesting that it operated on a more extensive and interconnected scale than previously documented.

Geospatial analysis allows us to identify patterns in urban development that were not readily apparent from the historical record alone, such as the clustering of processing plants or the spatial dynamics of industrial decline and regeneration. In correlation, the built environment, the architectural forms, and the important city infrastructures—as we observed in the Processing Plants dataset—changed rapidly and drastically.

The combination of historical, statistical, and geospatial analysis has proven to be an effective method for revealing both well-documented and previously unseen aspects of Gloucester's fisheries and urban development. By supplementing existing literature with new data and perspectives, it is possible to gain a more detailed and nuanced understanding of the city's peak as a fishing center, its subsequent decline, the socio-economic transformations that accompanied these changes, and how these shifts were reflected in both the built environment and marine ecosystems.

5.3. Limitations and Future Work

One important limitation to underscore is the preliminary nature of these findings. However, they offer a promising glimpse into the kinds of connections our data may reveal, allowing us to forecast long-term trends in resource exploitation and the socio-economic dynamics of Gloucester.

The challenges we face are largely inherent to historical research: scarcity and fragmentation, lack of uniformity, and issues with sample representativeness. Additionally, the digitization of large amounts of information, especially from older publications, often with poor-quality scans, is a time-consuming process that requires meticulous attention to verification and validation.

Up to this point, our work has primarily addressed socio-economic factors and human interactions with the environment. In alignment with the study's objectives, future efforts should increasingly focus on environmental variables. Future research needs to place greater emphasis on understanding how these ecological factors interact with the socio-economic elements already under analysis.

A critical next step will be to expand the Fishing Grounds dataset, which contains statistical data on fish landings. If sufficiently comprehensive for the period in question, this dataset will be essential for cross-referencing with other datasets, as it serves as the primary indicator of both fishery productivity and its impact on marine ecosystems. By linking fishing statistics with data on fishing fleets and population shifts, or examining the relationship between fish species and quantities caught with Gloucester's fishing companies, workforce, and processing plants, we will gain valuable insights into the broader dynamics of the industry in relation to urban settlement.

6. Conclusion

This article has outlined the approach and initial findings of a broader investigation into the industrialization of fisheries in Gloucester, Massachusetts. Our research offers critical insights into the socio-economic and ecological transformations that have shaped the region, while also acknowledging the current limitations and

the work yet to be done. As a foundational study, this work presents a starting point for future research on this topic, which will require further development of the datasets and a more comprehensive analysis of patterns and changes over time.

One of the contributions is the systematic digitization and accessibility of historical data on Gloucester's fisheries. While much of this information has been available in fragmented forms, the process of organizing, digitizing, and integrating these sources into a coherent dataset reduces barriers to conducting more nuanced analyses. These datasets must and will be published according to FAIR principles. Additionally, the thorough documentation of our methodological approach provides a transparent and replicable framework for future research.

The development of advanced data visualizations represents another core contribution. Visual tools are essential for illustrating complex socio-ecological processes, and the visual representations generated in this research serve as effective mechanisms for communicating intricate historical dynamics. These visualizations enhance our understanding of long-term patterns and provide a foundation for the application of similar techniques in interdisciplinary studies, particularly in fields such as environmental humanities and the history of urbanism.

It is expected that this research will contribute to the growing intersection of digital humanities and environmental humanities by integrating historical, ecological, and socio-economic dimensions. Through this interdisciplinary approach, it seeks to provide a more comprehensive understanding of the complex interactions between human society and the marine environment. By bridging these areas, this work not only enhances our understanding of the North Atlantic's fishing industry but also lays the groundwork for future interdisciplinary collaborations that can address broader questions relating to environmental challenges and historical change.

Acknowledgments

The ongoing research that has generated the results presented in this article is supported by the Fishing Architecture project team. We are grateful for the collective discussions, valuable insights, feedback, and unwavering support and friendship. We also wish to extend our thanks to Patrícia Reis, a master's student in the Faculty of Architecture at the University of Porto, for her enthusiastic collaboration.

Funding

Fishing Architecture is a research project funded by the European Union (ERC, Fish-A,101044244).

Conflict of Interests

The views and opinions expressed are, however, those of the authors only and do not necessarily reflect those of the EU or the European Research Council. Neither the EU nor the granting authority can be held responsible for them.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors.

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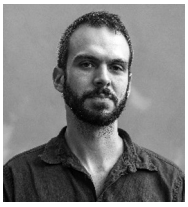
About the Authors



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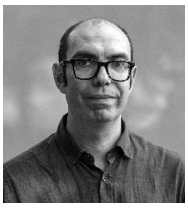

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Ocean and Society
2025 • Volume 2 • Article 9411
https://doi.org/10.17645/oas.9411

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Open Access Journal

Decarbonising Maritime Transport: The Role of Green Shipping Corridors in Making Sustainable Port-City Ecosystems

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Submitted: 14 October 2024 **Accepted:** 16 December 2024 **Published:** 6 February 2025

Issue: This article is part of the issue "Global Maritime Flows and Local Implications: A Worldwide Taxonomy and Glossary of Port City Regions" edited by Mina Akhavan (TU Delft), Yvonne van Mil (TU Delft), and Carola Hein (TU Delft), fully open access at https://doi.org/10.17645/oas.i442

Abstract

Maritime transport plays a crucial role in global trade and tourism, yet it significantly contributes to global greenhouse gas emissions, posing environmental challenges that demand urgent solutions. This article explores the innovative concept of maritime green shipping corridors, an emerging strategy aimed at decarbonising the shipping industry. By analysing the origins of green corridors from urban and transportation perspectives, the article outlines their evolution towards multimodal, zero-emission shipping solutions. It highlights the role of international frameworks, such as the International Maritime Organization Clydebank Declaration, in facilitating the transition to green shipping routes and the proliferation of zero-carbon fuels. The article also assesses the integration of renewable energy technologies, alternative fuels, and electrification in port operations, as well as the broader spatial and economic impacts on port-city ecosystems. With the potential to enhance urban sustainability, promote green logistics, and drive global decarbonisation efforts, maritime green shipping corridors represent a crucial framework for future research and policy development. However, the article highlights the need for further studies to evaluate the socio-economic and environmental impacts on local communities and regional planning.

Keywords

green shipping corridors; maritime transport decarbonization; renewable energy in ports; port-city ecosystem

1. Introduction: Green Corridors for Port-Cities in Transition

Maritime transport serves as the backbone of international trade and the global supply chain but also plays a pivotal role in the tourism industry. Shipping and ports are also essential elements of the blue economy—a concept that was drafted at the Rio+20 UN Conference on Sustainable Development in Rio de Janeiro in

June 2012; it is recognised as a framework for sustainable use of the ocean while balancing ocean-related economic activities with environmental concerns (Silver et al., 2015)—and play a vital function in maintaining blue growth across all sectors of the economy (Notteboom et al., 2022). Compared to bulk transportation, shipping is relatively energy efficient in terms of CO_2 emissions. Yet, maritime shipping, both for commodity and passenger flow, raises concerns about human health and environmental issues. Greenhouse gas (GHG) emissions from the maritime sector represent 2.8% of global emissions (Morante, 2022), with projections suggesting an increase to 17% by 2050 (Sinay, 2022). The shipping industry faces significant environmental challenges, including air and noise pollution, vessel discharges, port congestion, and marine ecosystem degradation (Jägerbrand et al., 2019).

To address these challenges, international frameworks such as the International Maritime Organization (IMO) 2020 and 2050 strategies have introduced tools and approaches aimed at sustainable practices in maritime operations. One of the most recent and innovative efforts towards decarbonising shipping and zero-emission fuels is to implement the "green shipping corridors" (hereinafter GSCs) concept, launched officially in 2021. Figure 1 shows the three phases of the shipping sector's transition to zero-emission fuels, highlighting the emergence of GSCs. In this preliminary phase, through national and international actions, learning and R&D, a complex framework of multiple technologies is tested in pilot projects. By 2023 (Phase 2), it was expected that technological developments and optimisation in the supply chain would help lower costs and, therefore, support the proliferation of zero-carbon fuel implementation and smoothen the transition process. In the final phase, the curve may reach a saturation point where zero-emission fuels become the primary shipping fuel (Smith et al., 2021).

Within the outlined framework, this article will provide a comprehensive review of the concept, tracing its origins from environmental, transportation, and planning perspectives, and discuss the potential impact on land and the sea. The aim is to understand the state-of-the-art studies and map a global taxonomy of the relatively new phenomenon of maritime green corridors, which can be used as a conceptual framework for future research lines in sustainable urban and regional studies. This article conducts a comprehensive desk research methodology to explore the concept and implementation of GSCs. Secondary data were collected from official documents, policy reports, and academic publications. The analysis incorporates a content review

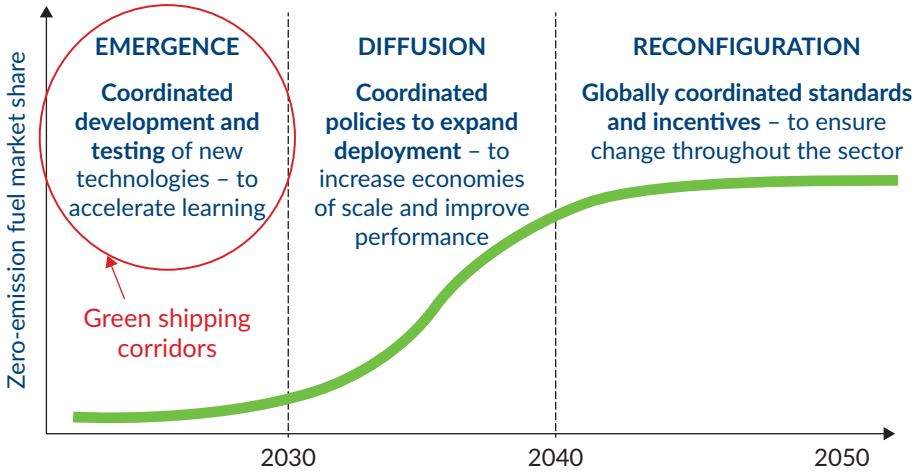

Figure 1. Three phases of the maritime industry transition to zero-emission fuels. Source: Talalasova and Fahnestock (2023, p. 2).

of international initiatives, such as the Clydebank Declaration, and a synthesis of multidisciplinary literature from environmental, urban planning, and transportation domains.

The structure of the article is as follows: Section 2 reviews the origins and conceptual foundations of green corridors (GCs), including urban and transportation perspectives. Section 3 focuses on the definition, implementation processes, and challenges of GSCs. Section 4 discusses the broader implications of GSCs for urban and spatial planning and port-city sustainability. Finally, Section 5 concludes with key findings, research gaps, and potential future directions.

2. Green Corridors: Origins, Concepts, and Definitions

2.1. Urban Green Corridors

The concept of GCs in transportation and shipping is relatively new, but its origins can be traced back to urban planning and design in the late 19th century. Early examples include Olmsted's "Parkways" in the United States and Ebenezer Howard's "Garden City" in England, regarded as pioneering visions of GCs in the early 20th-century town planning. These greenways were designed to create interconnected systems of environmental open spaces, integrating green infrastructure across urban and rural areas to combat air pollution (Hough, 1984). Over time, various movements and visions have emerged to minimise human environmental impact and preserve essential ecosystems by reimagining the relationship between cities and nature and linking natural elements into ecological corridors.

According to one of the forerunners of the contemporary GCs, they are "networks of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use" (Ahern, 1995, p. 134). In the literature, there are already many studies on the topic of GCs—especially from the 1990s onward—mainly from environmental and social science fields. A study by Aman et al. (2022) analysed 406 publications from the Scopus platform (up to mid-2022). Figure 2 shows a co-word analysis of the keywords, and five main clusters (topics) have been identified: (a) Agricultural land and ecology cluster (in red), (b) climate change and water conservation cluster (in green), (c) urban design and land use (in blue), (d) GC and transportation cluster (in yellow), (e) mining and soil erosion (in purple). The authors conclude that although the concept of GCs is not new, the literature is expanding slowly, and more interdisciplinary research is necessary.

2.2. Green Transport Corridors

As briefly discussed in the previous section, the significance of urban and ecological GCs is well documented in the literature (see also Korkou et al., 2023). For this study, it is worth making reference to transportation-related GCs. What is a transport corridor? Here, the definition of Arnold (2006) is used, which considers transport corridors as systems with two dimensions:

> Physical Dimension: one or more routes that connect economic centres within and across countries; these routes are composed of links and nodes that interconnect transport services; gateways are located at endpoints, connecting the corridor to the immediate hinterland.

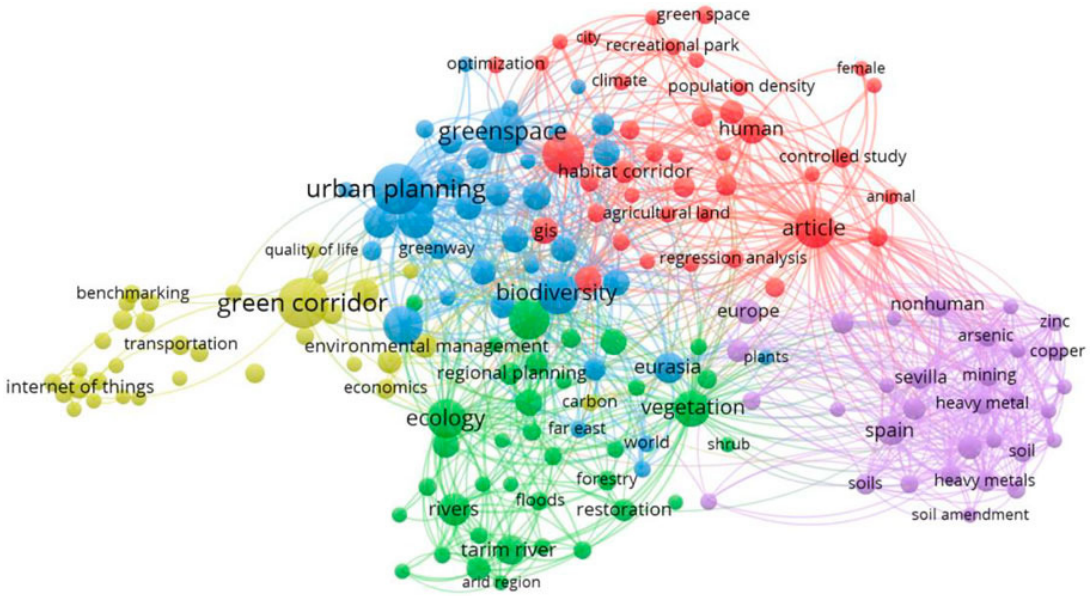

Figure 2. Co-word analysis of keywords from Scopus publications (1990–2022). Source: Aman et al. (2022, p. 2).

> Functional Dimension: as connectors between one or more countries or access providers to the sea for landlocked countries.

Moving from urban GCs to green transport corridors (GTCs), the concept evolves around the re-organisation of transportation systems regarding efficiency and sustainability issues. The initial ideas of GTCs were developed in North America and Scandinavian countries, which are traditionally "more environmentally sensitive." The initial concept concerned modes of transportation using clean energy (Miliauskaitė, 2011). What interests this study is GTC's more recent and developed vision in freight transport and supply chain: GTCs as integrated multimodal, efficient, and sustainable freight transportation solutions (Schröder & Prause, 2015). Freight-based GTCs in Europe were introduced as part of the EU's Freight Transport Logistics Action Plan in 2007: these integrated routes (GTCs) would enable freight to be transported with a reduced environmental impact via a combination of short sea journeys, rail, road, and inland waterways, and of relevant technologies, such as information and communications technology used in intelligent transport systems (European Commission, 2007).

According to the Swedish Logistics Forum, GTCs aim at reducing environmental and climate impact while increasing safety and efficiency and are characterised by:

- Sustainable logistics solutions with documented reductions of environmental and climate impact, high safety, high quality, and strong efficiency.
- Integrated logistics concepts with optimal utilisation of all transport modes, so-called co-modality.
- Harmonised regulations with openness for all actors.
- A concentration of national and international freight traffic on relatively long transport routes.
- Efficient and strategically placed trans-shipment points, as well as an adapted, supportive infrastructure.
- A platform for developing and demonstrating innovative logistics solutions, including information systems, collaborative models, and technology (Kyster-Hansen et al., 2011, p. 18).

3. Decarbonising the Global Maritime Sector: GSCs

3.1. Defining the Concept

Following long-term international efforts to reduce the environmental impact of maritime and shipping activities (e.g., since the 1970s, the International Convention for the Prevention of Pollution from Ships), the International Clydebank Declaration was launched at COP26 in November 2021, following the decarbonisation targets set by IMO. The Declaration aims to promote a coalition among ambitious governments, port(s), and operator(s) to reduce the GHG emissions of shipping routes (zero-carbo emissions ships) through public and private actions and policy measures. Being an innovative initiative, the first question here is the definition of "GSCs" and whether it is port-centric or cargo-centric.

For the Global Maritime Forum and Getting to Zero Coalition, maritime green corridors are specific shipping routes where zero-emission ships' technological, economic, and regulatory feasibility is catalysed by a combination of public and private actions (Global Maritime Forum, 2022). Others define such GCs as innovative systems of creating coalitions of stakeholders—to leverage national interest in the transition to zero-emission shipping in a way that impacts international shipping (Smith et al., 2021). GSCs are, in fact, specialised trade routes connecting major port hubs where zero-emission solutions have been implemented and supported (Talalasova et al., 2022).

Once fully developed, the green shipping corridor entails the different layers between two (major) ports as schematically drafted in Figure 3. Three main layers can be identified here: ports as nodes (land), shipping corridors and connectors (sea), and technology (energy, shipping, and land-based). The collaboration between

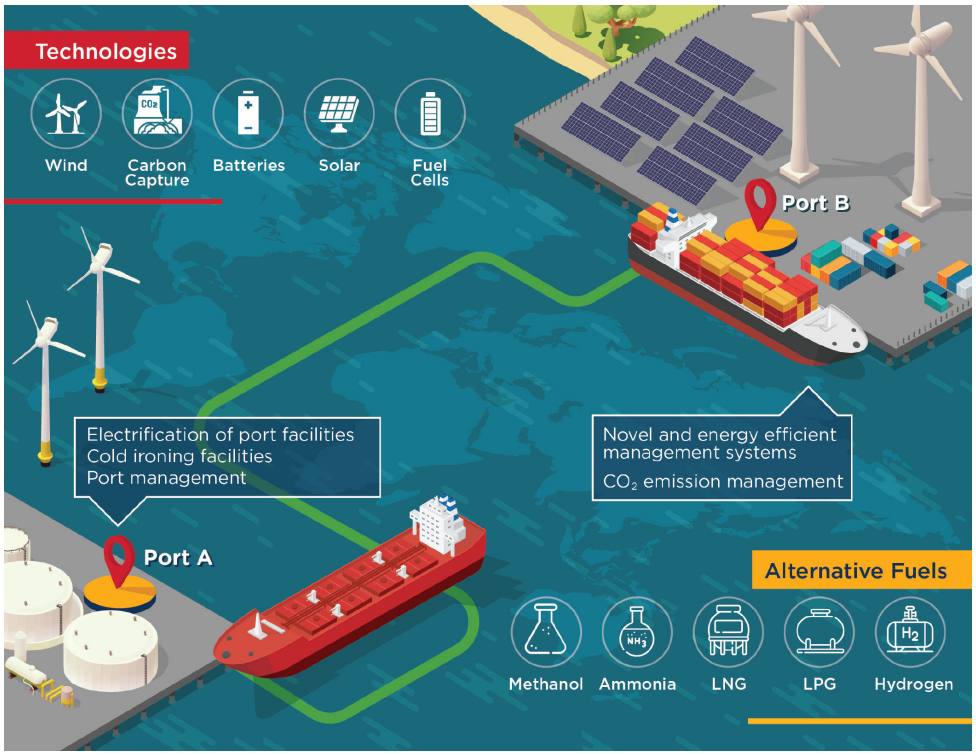

Figure 3. Schematic layers of the green corridor concept. Source: American Bureau of Shipping (2022, p. 2).

stakeholders will then leverage this system by creating a multilayer development plan where all the actors will follow a common objective(s) towards decarbonising maritime activities on land and sea.

The international organisation C40, which thrives on creating a global network of the world's leading cities that are united in action to confront the climate crisis, defines GSCs as "a shipping route on which zero-carbon emissions ships and other emissions reduction programmes are deployed, and emissions reductions are measured and enabled through public and private actions and policies" (C40 Cities, n.d.-a, para. 2). It is worth underlining that C40 has established the Green Ports Forum, which supports ports and cities in advancing maritime decarbonisation and the broader energy transition. It offers a platform for peer-to-peer learning, mobilising knowledge, and catalysing policies and programmes. Accordingly, C40 has created a network of 22 member cities—Auckland, Barcelona, Boston, Callao, Copenhagen, Dubai, Durban, Guangzhou, Los Angeles, Lima, New York, Newark, Oslo, Rotterdam, Seattle, Shanghai, Singapore, Stockholm, Sydney, Tokyo, Vancouver, and Yokohama—and their ports and support them in establishing their green shipping corridor and proposes the following actions:

- Developing special economic zones at the port-city interface to support innovative technologies and business models in tackling climate change.
- Considering best practices and successful programmes offered by C40 (e.g., Zero Emission Areas Programme of 2017; C40 Cities, n.d.-b).
- Tackling broader environmental issues by zero-emissions ships and green ports that contributes to reducing GHG.
- Fostering collaboration among ports and cities and public-private partnerships with the shipping and port-related industries.

3.2. State-of-the-Art Implementation Process and the Role of Actors

By 2023, 27 countries have signed the Clydebank Declaration: Europe (Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Great Britain, and Northern Ireland); North America (Canada and the United States); South America (Chile and Costa Rica); Oceania (Australia, Fiji, New Zealand, Palau, and the Republic of the Marshall Islands); North Africa (Morocco); East Asia (Japan, Singapore, and Republic of Korea); and the Middle East (UAE; United Kingdom Government, 2021). About 30 initiatives on GCs have been introduced by public and private stakeholders worldwide (Figure 4). The geography of the announced GCs shows a concentration in North America, (North and Eastern) Europe, and East Asia, which aligns with the region's strategies to decarbonise their economy. Yet, there are huge gaps; being an international sector, maritime transport is regulated by IMO at a global scale, so more countries should engage for a faster transition to the process of decarbonisation (PierNext, 2022).

Collaboration between governmental organisations and other stakeholders is necessary to ensure a promising global impact of GCs. A digital platform called Missions Innovation (see https://mission-innovation.net) monitors GSCs and has mapped various stakeholders looking for partnerships and, therefore, is interested in forming or supporting such corridors. Here is a selection of these stakeholders for each category:

- Government or regulatory authority: for example, (a) Port of Antwerp (Bruges), (b)The Research Council of Norway (investing in R&I and supporting international research to accelerate demonstration

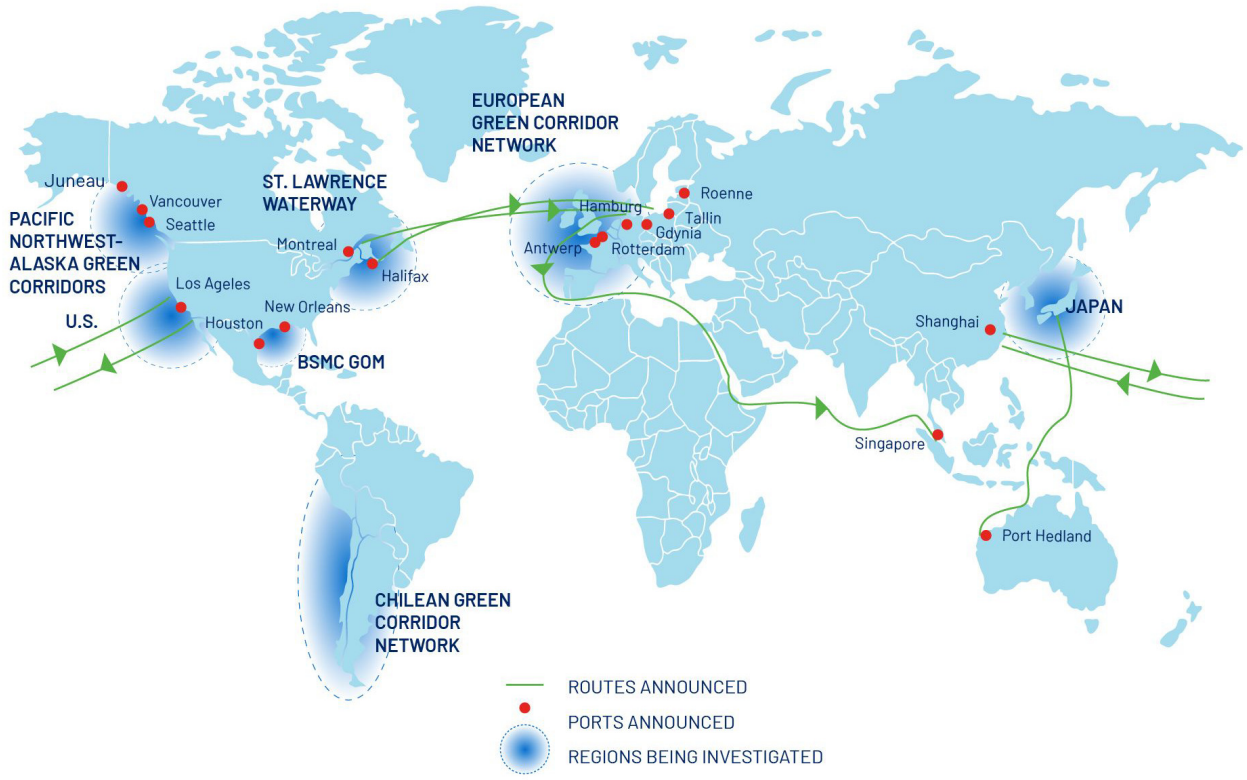

Figure 4. Global initiatives on GSCs (under development or established). Source: Hervas (2023).

and deployment of zero-emission fuel vessels and new ship technologies in GSCs); and (c) Korea Maritime Institute.

- Class society: for example, (a) ACUA Ocean, a UK-based start-up for zero-emission vessel provider that seeks the feasibility of a GSC between the Port of Aberdeen and Norway; and (b) ClassNK, a non-profit third-party certification body based in Japan, supporting stakeholders by providing knowledge and certifications to initiatives on environmental protection.
- Energy provider: For example, (a) Norwegian Hydrogen, which drives the green transition through the development and operation of green hydrogen infrastructure, aimed primarily towards heavy-duty transport and maritime customer segments; and (b) Australian-based Oceania Marine Energy, which is leading the decarbonisation of shipping in the Asia-Pacific.
- Knowledge community: For example, (a) C40 Cities (22 in total); (b) Newcastle University; (c) Fürstenberg Maritime Advisory; and (d) Institute of the North and SeaAhead in the United States.
- NGO: For example, Pacific Environment, a global environmental NGO based in the United States, focuses on empowering local communities with its Port for People campaign.
- Ports and terminal operators: For example, Thames Freeport and Dover Harbour Board in the UK, as well as the Port of Seattle and Port of Oakland in the United States.
- Shipyards and original equipment manufacturers: LR-Shipdesign AG based in Switzerland; Eltronic Fueltech A/S in Denmark; Azane Fuel Solutions AS in Norway.
- Technology provider: Spire Global based in Luxemburg; AMOGY and Zero Emission Industries based in the United States.
- Vessel owners and operators: Viridis Bulk Carriers AS, Amon Maritime AS, and Grieg Ammonia Distribution Vessels AS from Norway; E&S tankers based in Germany.

The geographic distribution of the proposed actors shows that (mainly Northern) Europe, the United States, and, to some extent, East Asia are taking the lead in showing interest in supporting such initiatives. The multiplicity of interested actors is promising. The knowledge community (including research institutions) shows a dominant interest in developing green maritime corridors. The balance between governmental, industrial, and research sectors (plus academia) has yet to be achieved by encouraging more stakeholders from various categories to collaborate in this initiative.

The world's first GSC was announced in January 2022 between two major ports in the United States (the Port of Los Angeles), China (Port of Shanghai), and C40 cities. This partnership between cities, ports, and maritime industries (including shipping companies and cargo owners) will create the first trans-Pacific GC in one of the world's busiest container routes, reduce GHG emissions from cargo flows, and support the shipping transition to decarbonisation. Based on their Green Shipping Corridor Implementation Plan Outline, the participants of this corridor strive to reduce carbon emissions from shipping and port activities and to address local community impacts. Figure 5 illustrates the conceptual framework of the Los Angeles–Shanghai Green Shipping Corridor, highlighting the collaborative process among key stakeholders and the "gate-to-gate" approach to emissions reduction. Focusing on emissions reductions at all stages of the shipping life cycle—from port operations to vessel transit—the corridor adopts a comprehensive approach that includes both on-land and at-sea solutions. This highlights its dual impact on local air quality and global decarbonisation.

The Los Angeles–Shanghai Green Shipping Corridor represents a pioneering collaboration among key stakeholders to achieve decarbonisation in maritime transport. Four stakeholder groups—carrier partners, port partners, cargo owner partners, and all partners—are tasked with specific goals to drive progress. Carrier partners aim to enhance technical and operational efficiency for participating shipping lines, targeting the deployment of zero-lifecycle carbon emission ships by 2030. They are also responsible for developing innovative solutions to improve the sustainability of shipping operations. Port partners play a crucial role by investing in clean marine fuelling infrastructure, ensuring reliable services for shore-based power, and reducing emissions from terminal operations. These efforts create the necessary foundation for adopting green technologies at ports. Cargo owner partners are tasked with contracting shipping services

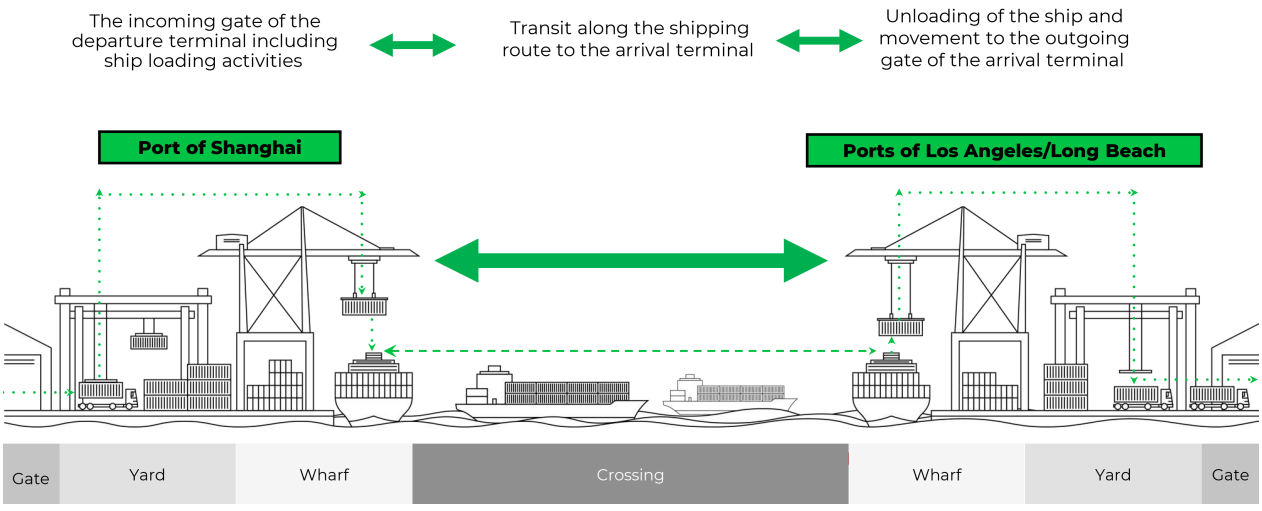

Figure 5. Schematic vision of the Port of Los Angeles–Port of Shanghai Green Shipping Corridor. Source: C40 Cities (n.d.-c).

that use zero-carbon emission technologies, committing to increased adoption over time. They also advocate for policy measures that make green solutions economically viable. All partners share responsibility for setting tangible CO_2 reduction goals, regularly reviewing progress, and identifying pathways for improvement. Together, they aim to support the feasibility and demonstration of the world's first zero-lifecycle carbon emission container ships, fostering innovation and sustainable practices across the shipping industry (C40 Cities, 2023).

This pioneering Los Angeles–Shanghai corridor is particularly significant as the initial foundation of an innovative framework for cross-value-chain collaboration starts at the local level: the cities and their ports in both cases of Los Angeles and Shanghai are run by their municipalities. In this regard, Alisa Kreynes, deputy director of ports and shipping for C40 Cities, stated at the C40 Ports Forum in 2021:

> We work at the city-to-city level, which makes things a lot more efficient than working at the state or national level. So, in the case of the United States and China, we were able to overcome some of the geopolitical tensions and complexities that were certainly not in our favour at that time. (LaBrecque, 2023, para. 7)

Therefore, in this example, the corridor is "port-centric" as it initiates from the port level, so the system priority settings and fuel choices are set based on the air quality issues and local community and environmental interests in both port-cities (Global Maritime Forum, 2022).

In contrast to the port-centric corridors are the "route-centric" ones (e.g., the West Australia-East Asia iron ore GC), which are not driven by the ports themselves but may originate from ambitious countries and their strategic interest, which vary from region to region. Here, GCs can contribute to national goals on sustainability in the following areas:

- Maritime competitiveness: GC strategy as a tool to modernise the country's maritime sector and to secure, future-proof, or strengthen the national maritime competitiveness.
- Energy leadership: GCs enable a country's transition by securing its position in the future energy market.
- Climate leadership: GCs contribute to the broader decarbonisation agenda and the global climate movement.
- Innovation and technology leadership: GCs secure the country's competitiveness in the global knowledge economy by entering into a new market for innovation and advanced technology.
- Strengthening trade partnerships: GCs secure national competitiveness in global trade flows by offering advantageous conditions for trade along significant routes (Talalasova & Fahnestock, 2023).

3.3. Green Shipping Corridors Implementation and Challenges in Energy Transition and Innovation

The implementation of such GCs is associated with adopting alternative fuels, renewable energy technologies, and the electrification of shipping operations. A significant aspect of establishing GSCs is the integration of renewable energy technologies within port operations. Ports are increasingly designed to minimise carbon footprint by optimising energy use and reducing reliance on fossil fuels. This transition is essential for achieving the decarbonisation goals set by international maritime organisations, which aim to substantially reduce GHG emissions from shipping activities (Camargo-Díaz et al., 2022). Incorporating renewable energy technologies

not only supports the operational efficiency of ports but also aligns with broader environmental objectives, such as those outlined in the European Green Deal, which emphasises the importance of sustainable energy practices in various sectors, including maritime transport (Ustolin et al., 2022).

Alternative fuels also play a crucial role in the decarbonisation of maritime transport. Fuels such as hydrogen, ammonia, and biofuels are being explored as viable options to replace traditional marine fuels. Studies indicate that the life cycle emissions of biofuels can significantly reduce GHG emissions compared to conventional fuels, showcasing their potential to achieve a more sustainable maritime sector (Q. Wang et al., 2023). Moreover, the use of ammonia as a shipping fuel has gained traction, although it raises concerns regarding secondary emissions and environmental impacts that must be addressed (H. Wang et al., 2023). IMO has set ambitious targets for reducing GHG emissions from shipping, with a commitment to at least a 50% reduction by 2050, necessitating the widespread adoption of these alternative fuels (Serra & Fancello, 2020).

The electrification of vessels is another critical component of maritime GCs. Hybrid electric systems and battery-powered ships are being developed to enhance energy efficiency and reduce emissions during operations (Torreglosa et al., 2022). The transition to electric propulsion systems not only lowers operational emissions but also aligns with the global push towards cleaner energy sources. However, the initial investment costs for these technologies can be high, which poses a challenge for widespread adoption (Y. Zhang et al., 2022). Economic incentives and supportive policies are essential to encourage investment in green technologies and infrastructure to facilitate this transition (see Qadir et al., 2021, for a review).

4. Potential Implications of Green Shipping Corridors for Urban/Spatial Planning and Sustainable Port-City Ecosystem

The implications of GSCs for cities and spatial planning are yet vague and to be discovered. However, GSCs may represent a shift towards sustainable urban development and integrated transport systems. Such corridors, which facilitate the movement of low-emission vessels and promote sustainable maritime practices, necessitate re-evaluating urban planning strategies to integrate these corridors effectively into territory and land use. This integration can enhance urban sustainability, improve connectivity, and foster economic growth while addressing environmental concerns.

The implementation of GCSs demands spatial planning and policy approaches that align transportation infrastructure with urban development goals. Jurković and Lovoković (2023) discuss that corridor planning should focus on creating synergies between transport systems and surrounding land uses, thereby enhancing the overall development value of cities. This approach ensures that GCs do not merely serve as transportation routes but also contribute to urban vitality and sustainability. For instance, integrating GCs can facilitate the development of multifunctional spaces that promote recreational activities, biodiversity, and community engagement (Z. Zhang et al., 2019). Moreover, planners and decision-makers must ensure that ports, as nodes of GSCs, are equipped with sustainable logistics infrastructure, including renewable energy facilities, alternative fuel storage, and electrification systems. Hence, GSCs will impact land use policies and redesign urban spaces to prioritise eco-friendly logistics hubs, improving connectivity between ports and hinterlands while minimising environmental impacts. As cities adapt to the increasing importance of maritime transport, there is a need to reserve spaces for port-related activities and infrastructure that support green shipping initiatives. H. Wang and Zhang (2020) highlight the importance of evidence-based

environmental planning in urban areas, which can guide city managers in enhancing and conserving GCs and ecological networks.

The establishment of GSCs also has implications for regional development. By enhancing connectivity between urban centres and ports, these corridors can stimulate economic growth and facilitate sustainable trade. Mao et al. (2023) show that developing international transport corridors (in the example of China–Europe) can improve regional green economic efficiency as a new overland trade between regions. Furthermore, the transition to GSCs can catalyse the development of green infrastructure, which is crucial for sustainable urban planning. Lennon (2014) discusses how green infrastructure can enhance ecological sensitivity in urban areas, promoting greater biodiversity and improving the quality of life for residents. Integrating GSC with the urban GCs can facilitate the establishment of ecological networks that connect green infrastructures, thereby enhancing biodiversity and providing essential ecosystem services.

GSCs can significantly impact the economic and logistical aspects of port-city interactions. Implementing such corridors encourages the use of advanced technologies and co-modality in freight transport, which can lead to increased efficiency and reduced GHG emissions (Penela et al., 2012). This shift towards greener logistics not only aligns with global decarbonisation goals but also enhances the competitiveness of ports by attracting environmentally conscious businesses and consumers (Song et al., 2023). Also, the development of green ports can serve as a model for sustainable development, providing valuable lessons for cities aiming to integrate sustainability into their economic frameworks (Nguyen et al., 2022). The strategic planning of GSCs can facilitate the integration of renewable energy technologies into port operations. Adopting renewable energy in ports is crucial for reducing the environmental impact of maritime logistics (Parhamfar et al., 2023). By aligning green shipping initiatives with urban energy strategies, cities can create a more sustainable and resilient infrastructure supporting economic growth and environmental stewardship.

Moreover, the governance and management of GSCs require collaboration among various stakeholders, including governmental bodies, private sector entities, and local communities. The involvement of diverse stakeholders is essential for successfully realising GTCs, as it fosters a sense of shared responsibility and collective action towards sustainability (Prause & Schröder, 2015). This collaborative approach can lead to the establishment of comprehensive policies that support sustainable urban development and enhance the resilience of port-city ecosystems against climate change.

GSCs can, therefore, represent a complementary effort for the complex and multidimensional concept of sustainability and sustainable development. Here, it is worth mentioning the three-pillar conception of sustainability (social, economic, and environmental)—introduced by Barbier (1987) in the mid-1980s, which today is known as a common view for a model of sustainable development (Purvis et al., 2019). While conceptualising the GSC, I suggest adding a fourth pillar to the sustainability concept: institutions and actors (governmental and non-governmental). Therefore, a schematic diagram of the four intertwined pillars for sustainable development of port-city regions connected to green maritime corridors and green ports is reimagined, as illustrated in Figure 6.

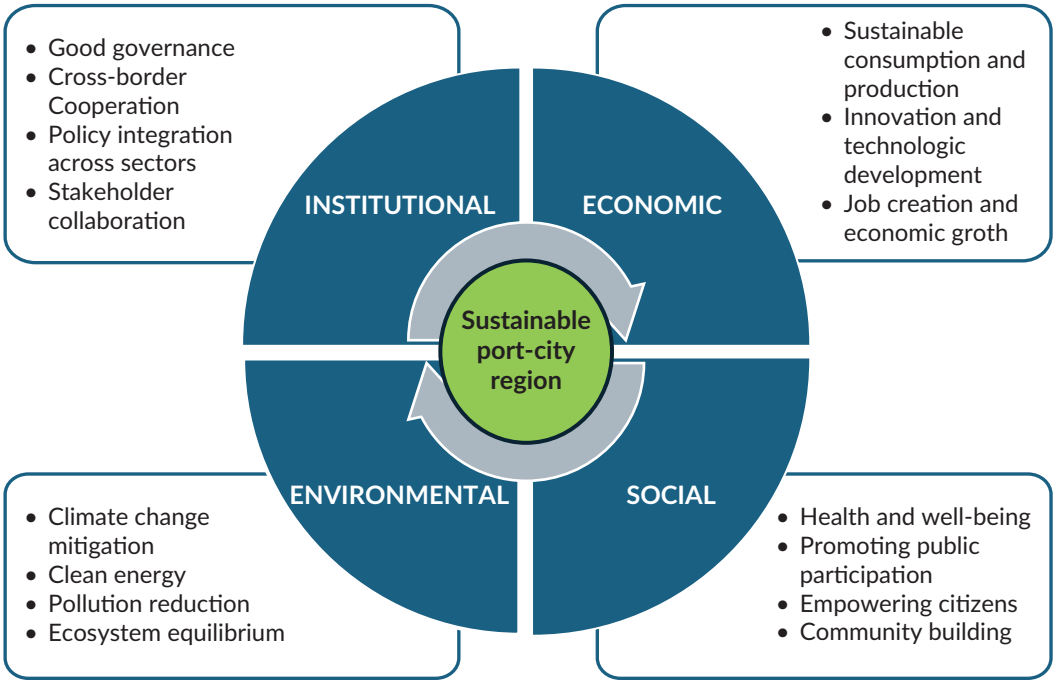

Figure 6. The four-pillar dimension of sustainable development of port-city regions connected to green maritime corridors.

5. Concluding Remarks: Rethinking Ports and Their Green-Blue Connection

The concept of GSCs and their environmental impacts within the broader topic of energy transition in the maritime sector is gradually gaining attention in different regions of the globe. Such corridors are pivotal in the ongoing transition towards sustainable shipping practices. They facilitate the movement of vessels with low-emission fuels and technologies, thereby reducing the environmental impact of maritime transport. The implementation of GCs is closely linked to the adoption of alternative fuels, renewable energy technologies, and the electrification of shipping operations.

On the other hand, GSCs create worldwide networks of nodes (ports and port-cities) and links (shipping routes), which necessitates a complex stakeholder configuration and collaboration. Offering favourable conditions for accelerated actions in terms of environmental policy, energy production, and shipping operations, GSCs can function as "special economic zones at sea," which should be expanded and linked to green ports on land. This will allow policymakers to enable an ecosystem with regulations and financial incentives to support the transition, for example, in lowering the cost of green fuel.

If we consider ports as nodes of connections and shipping corridors as links between these nodes, GSCs may also contribute to the energy transition of port-city-regions worldwide. However, disaggregated and transparent data is needed to undertake detailed studies on the extent of the state-of-the-art actions of such corridors and the technological and policy-related challenges. Moreover, being a new and rather complex global programme, no study is yet available on this concept's potential (positive and negative) impacts on the territory: port hinterland, their hosting city, and region. Empirical research is necessary to understand the spatial implication of the shipping energy transition on land (soil consumption, land use, etc.) and how it will be integrated (or not) with other GCs (urban and transportation). Although GSCs are turning points in the

zero-emission transition of the maritime sector and can create clusters of innovation for high-ambition ports and actors in the global supply chain, it is unclear to what extent local communities can benefit from such a transition. Here, I have outlined some challenges that raise questions for the future implementation and success of green maritime corridors, which would also become future research lines:

- Political and governmental support, along with the creation of a transborder collaboration among different countries: What is the role of regional policy and planning? Can the EU regional framework, such as the MSP, facilitate cross-border cooperation for implementing GSCs?
- A collaborative framework for joint action between various stakeholders: What tools and methods are needed to encourage cooperation among governments, industry, and academia? What are the implications for the private operators, and how does it impact the worldwide competitiveness of ports and shipping operators?
- Technological advancements and challenges: What is the role of the public sector in providing financial incentives and investing in R&I, start-ups, and the green technology industry?
- Interaction between the green maritime corridors, land, and local communities: How can community leaders be included in the implementation process for a just society?

Despite their potential, GSCs face significant challenges, including high implementation costs, technological uncertainties, and resistance to regulatory changes. More empirical research is needed to evaluate the socio-economic impacts of GSCs on local communities and regions. Studies on land use conflicts, soil consumption, and urban resilience are crucial to understanding how GSCs coexist with other urban green initiatives. Research on stakeholder collaboration is equally important to identify effective governance models that balance public and private interests while addressing the needs of vulnerable communities. Technological advancements in renewable energy, alternative fuels, and electrification must also be scaled up, requiring robust financial mechanisms and supportive policies.

Funding

This work was supported by Horizon.1.2—Marie Skłodowska-Curie Actions (MSCA), Project RePortFlows, under the Grant agreement ID: 101066680.

Conflict of Interests

In this article, editorial decisions were undertaken by Yvonne van Mil (TU Delft) and Carola Hein (TU Delft).

Data Availability

All data used in this research (mainly secondary) is open data, and relevant sources are provided in the text.

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