Port Cities and Evaluation: A Literature Review to Explore Their Interplay in Planning

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Abstract. Port cities constitute complex urban systems in which human settlement, production activities, and coastal resource uses intersect. Sustainable planning in these cities is critical due to the intricate relationship and interdependence between environmental phenomena and socio-economic processes. This literature review investigates the role of evaluation in the study of port cities by cross-checking the concepts of "evaluation" and "port cities". The Scopus database was queried to obtain publication data; then VOSviewer software was used for bibliometric analysis of the results. The analysis of the scientific literature identifies the themes, scale of application, key methodologies and evaluation issues found. Afterwards, the classification of scientific literature is differentiated by scale of application, topic, method, and evaluative problem. The results show how research tends to distinguish and separate the evaluation of the economic performance of the port, seen as transportation and logistics infrastructure, from the assessment of socio-environmental processes, referring to the urban waterfront and coast. This separation is reflected in the identified research gaps and suggests that the application of evaluation to the transformative processes of port cities must therefore promote the integration of the different dimensions involved, aiming for the recognition of the complexity of the values involved and pursuing Sustainable Development Goals.

Keywords: Port city · Evaluation models · Sustainable Development Goals

1 Introduction

Port cities represent a particular application category of urban and regional planning, configuring a complex interplay between human settlements, productive activities, and the use of coastal resources.

The concept of a port city encapsulates a delicate balance between physical, symbolic, economic, and cultural cohesion, resulting in a complex organism shaped by the intensity of the relationship between land and sea territories [1].

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Port cities have evolved symbiotically, with infrastructure development closely intertwined with settlement expansion, embodying an urban synecdoche [2]. However, technological advancements have led to the specialisation of port infrastructure, exacerbating tensions between productive activities and urban centres and necessitating administrative autonomy and separation between port and city institutions. That phenomenon has led to consider port and city systems as separate entities [3].

As noted by Zheng et al., [4] a port city comprises two distinct systems. The first is the port system, marked by logistics, imports, exports, and large-scale infrastructure projects propelled by technology, efficiency, and competitive forces. The second system encompasses its interaction with the city, characterised by social, ecological, and economic diversity, facilitating the development of urban and regional infrastructure.

Ports act as catalysts for the economic, social and cultural prosperity of cities stimulating employment generation, facilitating trade, and supporting industries and tourism, thus enhancing the economic vitality of port cities [5, 6].

Despite their economic benefits, port operations have a huge environmental impact on cities through air and noise pollution, soil contamination, habitat destruction, and traffic congestion. These issues are leading civil society to keep even more attention to social and environmental issues concerning port activities [4].

Port cities, being complex urban environments, require careful planning and management due to their significant economic, social, and environmental impacts.

To interpret and understand intervention at various levels of transformation and development of port cities the application of evaluation models could play a crucial role in port cities by helping to assess, monitor and guide their sustainable development [7].

Port cities present themselves as pivotal centres for the pursuit and implementation of Sustainable Development Goals (SDGs) [8], both through shared, inclusive, and regenerative planning policies (goals 10 and 11); as well as in the implementation of circular economic models capable of generating wealth and investments at the territorial level (goals 8 and 12); and finally, preserving and restoring marine and terrestrial ecosystems, countering the effects of climate change (goals 13, 14, and 15).

Adopting sustainable development strategies for port city ecosystems means focusing on reducing negative impacts and fostering cooperation among different stakeholders.

Port cities, being complex urban environments, require careful planning and management due to their significant economic, social, and environmental impacts [9].

By assessing the effectiveness of policies, projects, and interventions, evaluation methods help ensure that port cities meet the goals of sustainability [10]. Furthermore, evaluation methodologies enable the various stakeholders to make informed choices, understanding the consequences of various development decisions on the city's infrastructure, economy, environment, and society.

The research intends to investigate what is the state of the art in the application of evaluation models to the analysis of processes concerning port cities and what recurring and effective methods can be deduced for the study of transformations of port cities. In order to seek answers to these questions, it was decided to conduct a review of the scientific landscape, investigating the Scopus database, and crossing the concept of evaluation with that of port cities.

The contribution is divided into three parts: in Sect. 2 the methodology and the functional tools for bibliometric analysis are presented; in Sect. 3 the results were elaborated and refined through bibliometric maps and defined criteria, identifying the main thematic groups in which research concerning evaluation applied to the city-port context can be attributed. Finally, Sect. 4 provides a discussion of the results and the conclusions.

2 Material and Methods

In order to answer the main research question, as presented above, it was decided to conduct a literature review, questioning the Scopus database [11–13], using a two-step advanced search (Fig. 1).

The search query is the combination of the terms "evaluation" or "assessment" and "port city", focusing on results that contain the word 'port', and its variants, within the title, abstract, or as a keyword.

The subject fields explored include Environmental Science, Engineering, Social Sciences, Computer Science, Econometric Sciences, and Decision Sciences.

The query results in a large number of documents, about 3262, to be exported in CSV format.

This first set of results has therefore been analysed using the VOSviewer software [14], through a co-occurrence analysis of authors' and index keywords, aimed at the realisation of a bibliometric map [15]. The Network Visualization of the co-occurrence map consists of a cloud-like layout, in which the nodes are filled with the keywords that recur at least 20 times in the searched documents, and whose dimension is directly related to the number of times they are found; the links between the words represent the strength of the bond between two keywords, i.e. the number of times they are co-occurred. Within the map, it is possible to identify the division of keywords into different coloured clusters, which represent special groups of elements with a higher degree of interconnection strength, which allow for understanding thematic and qualitative information [16].

The findings obtained from the bibliometric map, which will be explained hereafter, have led to the decision to narrow the field of investigation by refining the search query.

The terms "port plan", "waterfront", and "maritime planning" were added to the previous string, as well as "analysis", "method", "assessment", "evaluation", "scenario", and "process", searching the database for documents that use or contain these keywords in their title and abstract. Moreover, subjects have been narrowed down, focusing on the topics that carry the most relevant number of documents and are most closely related to the research field: Environmental Sciences, Engineering, Social Sciences, and Computer Science. To further refine the results, only journal articles and conference papers published in English have been selected, targeting only the 2010–2024 publication interval, as it contains the most representative number of articles.

A total of 185 results have been obtained and analysed iteratively through the VOSviewer software; a second bibliometric keyword co-occurrence map was then built, with a minimum recurrence threshold of 5 times, highlighting further significant clusters.

Finally, the resulting 185 publications of the refined search have been examined in detail and selected according to the following criteria: source availability in the associated databases; helpfulness to the research question; consistency with the clusters identified

in the related bibliometric map; and the possibility of deriving an evaluation method. The step-by-step filtering, yielded a result of 39 articles, which were then assembled into a classification table. The chosen articles were therefore organised according to four main criteria: the scale of application of the proposed research, whether it deals exclusively with port processes, port-city interaction, or those affecting the regional scale; the topic mainly covered; the evaluation method in detail explained and employed; finally, the main evaluation problem addressed.

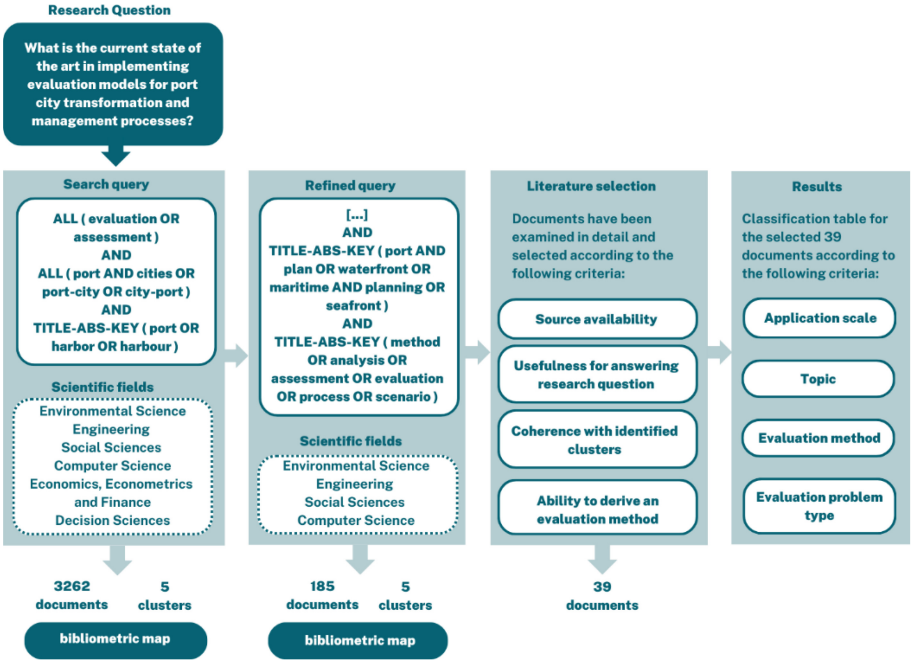

Fig. 1. Methodological approach scheme.

3 Results

The first phase of the research yielded 3262 results, considering the intersection between the concepts of evaluation and port cities, exploring Social Sciences, but also Engineering, Environmental Science, Decision Theory, Economics, and Computer Science. This group of outcomes presents a rather broad and varied distribution, providing information of a global nature regarding publications dealing with the evaluation of port city processes.

The Network Visualisation of the co-occurrence bibliometric map (Fig. 2) displays how the most recurrent keywords are organised around 5 main clusters, arranging themselves according to the relative correlation between them, and therefore according to a

common semantic value. The clusters on the right (marked in blue and green, respectively) represent scientific contributions concerning air pollution, caused using fossil fuels for ship operation; closely related to these are, of course, those covering environmental monitoring, as well as water and coastal sediment pollution. Among them, it is interesting to note the presence of a small cluster of research dealing with the evaluation of health risks associated with exposure to environmental pollutants. The remaining groups (in orange and yellow) centre around the themes of the port, both as a transport infrastructure and as an urban issue; but also, around the assessment of risks and impacts due to climate change and extreme natural events.

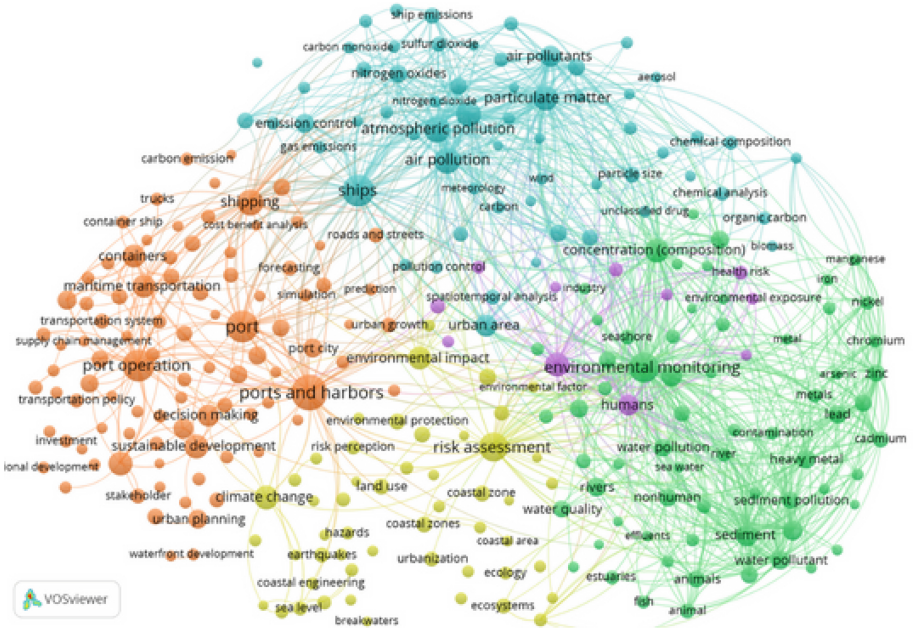

Fig. 2. VOSviewer network visualisation of co-occurrence map based on 3262 documents.

In the second phase, search terms were narrowed down in order to arrive at more detailed and relevant information from a research demand perspective. Therefore, only the most relevant disciplinary fields were considered, and the research period was narrowed down between 2010 and 2024 since it contains, with a good approximation, the most significant number of publications. The 185 results obtained were analysed in a second bibliometric co-occurrence map (Fig. 3), leading to the identification of five thematic clusters.

The keyword cloud presents a layout in which two main groupings are recognisable: in the right half (marked in dark and light blue) are the keywords related to logistics, supply chains, and analogously transportation development and port operation; in the left half, instead, there are two related clusters (in shaded green), namely urban planning and sustainable development, alongside environmental planning and monitoring. The sharp polarisation of the graph shows how the scientific literature tends to treat the

topics of "city" and "port" separately and not in an integrated manner, assessing only the operational aspects of economic performance on the one hand, or dealing with urban transformation and environmental issues on the other. Furthermore, the occurrence of terms such as "risk assessment" and "decision support system" in the operational port clusters might indicate particular publications dealing with risk management in the port domain; and, again, it can be seen that the logic of sustainability and ecology are more integrated in urban planning. In the middle-low part of the cloud, a last small cluster can be distinguished, represented by the keywords "decision making", "fuzzy mathematics", "analytic hierarchy process", which indicates how the field of evaluation is equally distant and still rather marginal, in terms of publications, compared to the other clusters.

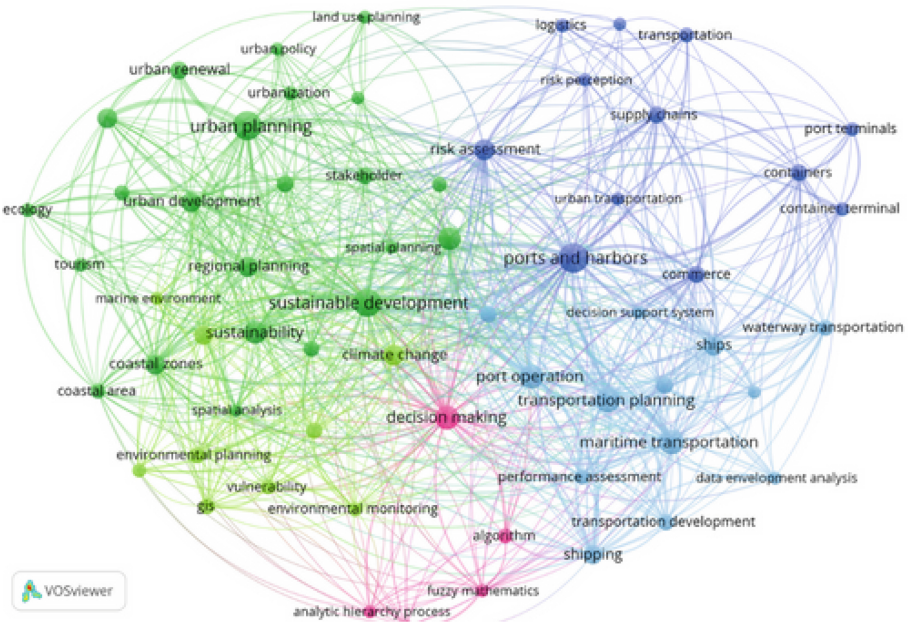

Fig. 3. VOSviewer network visualisation of co-occurrence map based on 185 documents.

Subsequently, publications were manually filtered based on resource availability, relevance to the research question, coherence with the aforementioned clusters, and the ability to clearly derive an evaluation method.

The 39 selected documents were classified into a classification table (Table 1). By aiming to understand potential trends or common practices in publications, the following table presents an organisation of the examined literature by linking specific evaluation methods to particular themes and their corresponding spatial scope.

Besides authors, title and year of publication, four classification categories were identified: the application scale of the analysed process, the main theme investigated, the method used to address the specific evaluation problem.

City-Port interaction, refers to the dynamic and multidimensional relationship and interdependence between City and Port.

Table 1. Classification table of the analysed articles.

Application scale	Topic	Year	Author(s)	Evaluation method	Evaluation problem type
City-Port interaction	Heritage	2022	Daldanise, G. et al.	Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) + Geometrical Analysis for Interactive Aid (GAIA)	Preferable scenario selection
		2013	De Rosa, F. et al.	Comparative method using sustainability indicators	Indicator selection
	Natural landscape	2022	Martin, R. et al.	Delphi Survey + Analytic Hierarchy Process (AHP)	Ranking of alternatives + Indicator selection
		2019	Martin, R. et al.	Delphi Survey	Indicator selection
	Port Planning	2012	Cerreta, M. et al.	Integrated Spatial Assessment (ISA)	Impact assessment
	Risk management	2024	Chondrogianni, D. V. et al	Method applying Bioclimatic Index	Ranking of alternatives
		2022	Chondrogianni, D. V. et al.	Method applying Bioclimatic Index	Ranking of alternatives
		2022	Guan, C. et al.	Decision-Making Trial and Evaluation Laboratory (DEMATEL) - Interpretive Structural Modeling (ISM) - and Social Network Analysis (SNA)	Performance levels
		2021	Saleh, D. et al.	Spatial Analysis + Analytic Hierarchy Process (AHP)	Performance levels + Indicator selection

(*continued*)

Table 1. (*continued*)

Application scale	Topic	Year	Author(s)	Evaluation method	Evaluation problem type
	Urban Planning	2024	Fan, M. et al.	Method applying Space Syntax Theory's indicators	Performance levels
		2020	Andrade, M. J. et al.	Qualitative and quantitative indicator-based method	Performance levels
		2020	Cerreta, M. et al.	Sustainability indicators (SI) + Role-Playing Method (RPM) + Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)	Preferable scenario selection
		2020	Cerreta, M. et al.	Method applying Survey + Likert scale evaluation	Indicator selection
		2020	Jardas, M. et al.	PROMETHEE	Preferable scenario selection
		2019	Schipper, C	Comparative method applying Green Port Policy (GPP) + Sustainable Development Goals (SDGs) framework	Indicator selection
		2019	Ignaccolo, M. et al.	Method applying Level of Service (LOS) and Utility	Performance levels
		2017	Schipper, C	Sustainable Integrated Condition Index (SICI)	Ranking of alternatives + Indicator selection

(*continued*)

Table 1. (*continued*)

Application scale	Topic	Year	Author(s)	Evaluation method	Evaluation problem type
		2013	Nicolini, E. et al.	Community Impact Evaluation (CIE) - Novel Approach to Imprecise Assessment and Decision Environments (NAIADE)	Ranking of alternatives
		2010	Cuturi, C	Method applying Sustainability indicators	Performance levels
Port	Port externalities	2022	Tovar, B. et al.	Data Envelopment Analysis (DEA)	Impact assessment + Performance levels
		2020	Viana, M. et al.	Health impact assessment (HIA)	Impact assessment + Performance levels
		2017	Papaefthimiou, S et al.	Quantitative and cost indicator-based method	Impact assessment + Performance levels
	Port Planning	2021	Majidi, A. et al.	Stepwise weight-assessment ratio analysis (SWARA) + Measurement of alternatives and ranking according to compromise solution (MARCOS) + Combined compromise solution (CoCoSo) + Technique for order preference by similarity to ideal solution (TOPSIS)	Ranking of alternatives

(*continued*)

Table 1. (*continued*)

Application scale	Topic	Year	Author(s)	Evaluation method	Evaluation problem type
		2020	Ignaccolo, M. et al.	Comparative method applying ASI (Avoid/Reduce, Shift/Maintain, Improve) analysis + ASI/Sustainability matrix	Indicator selection
		2020	Molavi, A. et. al.	Comparative method applying Smart Port Index (SPI) indicators	Indicator selection + Performance levels
		2019	Hill, R. J	Multi-criteria analysis (MCA)	Preferable scenario selection
	Risk management	2021	Dhanak, M. et. al.	Hybrid multi-modal simulation model	Performance levels
		2018	Yang, Z. et al.	Cost Benefit analysis based on Evidential Reasoning (ER)	Performance levels + Feasibility Evaluation
	Transportation and logistics	2023	Celik, M. S	Semi-structured interview + SWOT (Strenght, Weakness, Opportunity, Threat) + TOWS (Threat, Opportunity, Weakness, Strenght) + Analytic Network Process (ANP)	Preferable scenario selection
		2021	Sirotić, M. et al.	Survey + SWOT (Strenght, Weakness, Opportunity, Threat) + Gap analysis	Preferable scenario selection
		2020	Mou, N. et al.	Fuzzy Analytic Hierarchy Process (FAHP) + Entropy model	Ranking of alternatives
		2020	Feng, H. et al.	Analytic Hierarchy Process (AHP)	Ranking of alternatives

(*continued*)

Table 1. (*continued*)

Application scale	Topic	Year	Author(s)	Evaluation method	Evaluation problem type
Regional	Heritage	2016	Pourebrahim, S. et al.	Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) + Fuzzy Analytic Hierarchy Process (FAHP)	Ranking of alternatives
	Port externalities	2024	Madhumitha, R. et al.	Spatial Analysis + Analytic Hierarchy Process (AHP)	Impact assessment
	Risk management	2023	Hemmerling, S. A. et al	Social Return on Investment (SROI)	Preferable scenario selection + Impact assessment
		2022	Amoura, R. et al.	Spatial analysis using Geographical Information System (GIS)	Performance levels
		2016	Zanetti, V. B. et al.	Method applying Socio-Environmental Vulnerability Index for Coastal Areas (SEVICA)	Performance levels
		2013	Messner, S. et al.	Spatial analysis using Geographical Information System (GIS) + Cost Benefit analysis based on Net Ecosystem Services Analysis (NESA)	Performance levels + Feasibility Evaluation
	Transportation and logistics	2023	Fisher-Holloway, B. et al.	Spatial analysis using Geographical Information System (GIS)	Resource Allocation

Research into the city-port dynamic represents a focal point for numerous studies exploring decision-making processes and transformative endeavours within urban waterfronts. These investigations also delve into evaluative inquiries regarding the impacts of both natural phenomena and human activities. They share a holistic interest in integrating infrastructure, settlements, and the surrounding environment.

Daldanise et al. [17] delve into the potential for implementing planning and regeneration strategies for waterfronts, centred on heritage re-use. Their research proposes the definition of a decision support system employing multicriteria evaluation, showcasing the transformative potential of cultural-led urban development. Meanwhile, De Rosa et al. [18], conducting a comparative research of adequate indicators, advocate for the Historic Urban Landscape (HUL) framework as a guiding light for the regeneration of historical urban waterfronts, underscoring its symbiotic relationship with the layered urban fabric.

Martin et al. [19, 20] conduct interviews to stakeholder to derive soft indicators facilitating a nuanced understanding of the interplay between natural landscapes and tourist port infrastructure impact. Their prioritisation of integration actions underscores the need for holistic planning approaches.

By proposing an innovative Integrated Spatial Assessment protocol, Cerreta et al. [21] advocate for a comprehensive evaluation framework that incorporates environmental, social and economic indicators alongside spatial analysis and decision-making processes.

Strategies for adapting to extreme weather phenomena are analysed by Chodrogianni et al. [22, 23], through a quantitative ranking of various waterfront planning solutions based on bioclimatic performance, and by Guan et al. [24], who propose a methodology for analysing and evaluating natural and infrastructural risk factors, aimed at supporting the development of plans for the safety of port settlements. Saleh et al. [25] use remote sensing techniques for the identification of geomorphological risk areas, together with the evaluation of the most vulnerable anthropized areas, based on specific land use.

The topic of urban planning is particularly explored: Fan et al. [26] and Ignaccolo et al. [27] use the calculation of various indices to quantify the degree of pedestrian accessibility of coastal settlements with the waterfront and port area; Andrade et al. [28] and Cuturi [29] address comparative studies of different port cities in search of scalable indicators useful for replicating successful strategies. Schipper [30, 31] proposes a set of indicators to assess the sustainability of port city planning, correlated with the SDGs. Through the application of a specific index (Sustainable Integrated Condition Index) for the evaluation of various case studies, it is shown that alternatives where economy, society, and environment are more integrated are those with the best performance. Nicolini et al. [32] also resort to a set of multidimensional indicators, applying it to the ranking of strategic design alternatives for the port city of Palermo. Jardas et al. [33] use the PROMETHEE multicriteria evaluation method to assess the preferable development scenario of a city on the Croatian coast, among various possible strategies. Finally, Cerreta et al. [34, 35] construct a set of quantitative and qualitative indicators for the regeneration of Naples port city system. By applying the PROMETHEE multicriteria method, the preferred transformative scenario was selected.

Port, refers to its infrastructure aspect, the management and planning processes of port functions, as well as the external effects they can produce.

Papaefthimiou et al. [36] tackle the issue of externalities, particularly focusing on measuring the pollution stemming from port activities on the surrounding environment. They devise quantitative indicators aimed at economically assessing the impact of pollutants, drawing insights from operational data across a range of ports. Moreover, Tovar

et al. [37] employ a mathematical approach to compute the social and environmental external costs attributed to ship pollution in several Spanish cities. Instead, Viana et al. [38] undertake a Health Impact Assessment, establishing a direct correlation between ship pollutant emissions and mortality and disease rates in diverse case studies.

Port planning is approached by selecting appropriate indicators, exemplified by Ignaccolo et al. [39], who introduce a methodology linking suitable quantitative measures with diverse qualitative strategies for sustainable development. Similarly, Molavi et al. [40] devise indicators influenced by the Smart Port Model, covering environmental, energy, operational and security aspects of the port. Majidi et al. [41] employ the TOPSIS multicriteria method to assess sustainability performance across various ports in Iran. Hill [42] adopts this multicriteria approach also for his research, evaluating the preferred scenario within specific port development projects and emphasising the necessity of a decision support system to manage conflicting interests among stakeholders.

Dhanak et al. [43], using a multi-modal simulation model, predict the effects of extreme weather events on the operability of transport chains, evaluating the different levels of adaptation and infrastructural resilience of the port. Yang et al. [44] apply a Cost-Benefit Analysis to assess the feasibility of climate change adaptation interventions in relation to the magnitude of the risks encountered.

Using a qualitative methodology based soft data collected through surveys, Sirotić et al. [45] propose a strategic perspective for the sustainable development of transport in the Adriatic Sea; Celik [46] adopts the Analytic Network Process (ANP) to identify the optimal alternative among various development proposals in the context of trade between the Mediterranean and China. In the Chinese context, Feng et al. [47] employ the Analytic Hierarchy Process (AHP) multicriteria method to classify the most efficient ports in terms of logistics and transportation within a specific region. Similarly, Mou et al. [48] utilise Fuzzy-AHP method for assessing the economic development potential of ports in the Yangtze Delta context.

Regional, refers to a territorial and broader dimension in which urban and port dynamics influence a larger spatial context.

Pourebrahim et al. [49] apply the TOPSIS method to various alternative scenarios aimed at conserving cultural and natural heritage, endangered by anthropogenic phenomena. Subsequently, the Fuzzy-AHP method is used to establish a hierarchy of priorities among different conservation areas.

Madhumitha et al. [50] assess the impacts generated by infrastructure and port activities on the coast and hinterland, using satellite observation data. Additionally, they adopt the AHP method to determine the extent of impacts across different coastal settlements, employing specific socio-environmental indicators.

The use of spatial analysis methods and Geographic Information System (GIS) techniques is particularly significant for risk management. Amoura et al. [51] employ remote sensing technologies and mathematical methods to assess and predict the extent of coastal flooding due to future sea level rise, mapping the at-risk areas; similarly, Zanetti et al. [52] proposes a combined index to jointly assess vulnerability to coastal and inland hydrological hazards. Messner et al. [53] develop a prediction framework to evaluate sea level rise in port areas and the associated hydraulic risk, additionally proposing

a methodology to measure the economic impact of these phenomena and support the planning of adaptation interventions.

Hemmerling et al. [54] present a participatory approach for assessing the social impact of potential coastal restoring interventions, applying the Social Return on Investment (SROI) framework. The results demonstrate a convergence between social and environmental evaluations.

Fisher-Holloway et al. [55] utilise spatial analysis techniques such as Cluster analysis and Kernel density analysis within GIS to pinpoint the location of logistics services. This approach supports decision-making processes within port-hinterland transportation systems.

4 Discussion and Conclusions

After reviewing the vast literature dealing with the application of evaluation methods in the port city domain, it is evident the extent of the investigated field. Studies address a spectrum of scales, from the circumscribed area of port operations to the broader territorial context. This inquiry makes clear how entangled are the social, economic and environmental values involved in port cities.

Review of the research literature reveals a differentiation in the proposed evaluation methodologies: some studies use quantitative approaches, exploiting mathematical models to quantify the performance levels of particular targets, or to express values in econometric terms; others rely on the soft data gathered from qualitative approaches as common in social survey techniques; and others mix qualitative and quantitative indicators to capture the complexity of port city ecosystems.

In addition, the methods examined differ considerably depending on the topic: urban and port planning assumes evaluation models in order to make the best choices, based on objectively defined criteria, in support of policy-making; risk management is concerned with predicting potential effects due to more or less predictable extrinsic factors, while port emissions assessment focuses instead on the social and environmental effects already produced; logistics and transportation development are analyzed to maximize the efficiency in resource use and resulting economic performance provided; landscape and heritage assessment, by contrast, invokes the need for tools to recognize alternate values, such as environmental, social and cultural. In this sense, a research gap arises, namely the involvement of stakeholders and communities in transformative processes. While some of the research discussed explores the interplay between stakeholder interests and the proper methods of evaluation and quantification, exhibiting interesting outcomes, and succeeding in simultaneously capturing social and economic preferences; other studies fail in this task, coming up with solutions that only partially reflect the complexity of port cities.

Given the deep entanglement of economic vitality, community and natural environment, port cities require rigorous evaluative approaches to capture the interdependence among all the factors and values recalled. Examining the landscape of academic publications, this literature review offers a systematization of evaluative methods and case studies for obtaining planning solutions in several topics.

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