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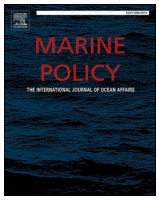

Twenty years of sustainable development and port authorities: A critical review of the literature

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ABSTRACT

Port management reflects a process of transformation and globalized social and socioeconomic evolution that must contribute to the era of the green transition. In this context, the main objective of the study was to detail and clarify the key epistemological characteristics between sustainability and the role of port authorities through a critical review of the relevant literature. For this analysis, the data reviewed covered a selection of 112 documents with the highest academic rigor that promote changes in port management. The proposal concludes that academic evidence demonstrates a positive and demonstrative relationship regarding the shift in the administrative role, focused on an ecosystem-based model with transformative potential for the green transition of port cities.

1. Introduction: evolution of port sustainability

At the global level, port regions are important nuclei of economic development. This development is well analyzed in the academic literature, with extensive studies that analyze profitability or efficiency from very different perspectives and approaches. Among others and in chronological order are the contributions of Tonzong [1], Barros and Athanassiou [2], Park and Prabir [3], Ducruet and Lee [4], Cullinane and Wang [5], Rios and Macada [6], De Langen [7], Stopford [8], Rosas and Torres [9], Notteboom [10], Haralambides [11], Liu and Hoon [12], Christodoulou and Cullinae [13], and Dong et al. [14].

The transitions of ports toward approaches supporting sustainable development materialize in two moments of rupture in classic port studies. The first is found with the appearance of the first voluntary codes of conduct [15,16], identifying the main environmental problems affected by port activities. The obligation to progressively implement a culture of quality and excellence [17], as well as promote port development, is exemplified in the change in social values regarding the administration and management function of the three E's—economics, efficacy, and efficiency [18–20]. Hence, the progressive and continuous implementation of systems and processes in compliance with these standards affects the environmental state, the conditions of emissions, the quality of the relationship between the environment and good management of economic resources, and the perspective of stakeholders in environmental and economic governance [21].

Kotowska [22] argues that the transformation from a preindustrial to an industrial society implies profound social and economic changes. Although there is extensive literature on port transformation [23,24], the interconnection between port authorities and transformative ecosystem changes shows a clear research gap, as exemplified in Table 1 [25–28], with a total of N = 46 cases in which the port authorities are viewed exclusively, compared to N = 3402 cases in which the focus of the analysis includes the port itself.

On the other hand, another line of literature refers to the port as changing phenomena in the ecological transition. For example, it is argued that more surveillance and integration of port activities are necessary to support an ecosystem approach, environmental protection and sustainable development [29].

In addition, port development, whether the impact of its activity or the monitoring of its negative externalities, must be managed by port

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Table 1
Research gap between "transformative change" and port authorities and/or ports.

No. of cases	Main algorithm
N=46	TITLE-ABS-KEY ("port authorities") AND TITLE-ABS-KEY ("transition" OR "transformative change" OR "transfor *") PUBYEAR < 2024
N=3402	TITLE-ABS-KEY ("ports" OR "port authorities") AND TITLE-ABS-KEY ("transition" OR "transformative change" OR "transfor *") PUBYEAR < 2024

Source: own elaboration according to cases estimated from Scopus (30/12/2023)

managers in a way that balances economic development and local community needs [30,31].

Other little-explored narratives highlight the role of port authorities by exploring their contribution to ecosystem services [32–34].

In this framework, the role of the port authorities is very important in the fulfillment, among other aspects, of three standards of results and processes of management and sustainable development. The first is the goal of improving "environmental management" [35–37] on the basis of the idea of economy, effectiveness, and efficiency. Second, the objective of converting port development into the image of a "sustainable port" [38–40] is based on interactions among the social, economic, environmental and institutional systems. Finally, the "green port" stage addresses the issues of governance, corporate social responsibility, the role of stakeholders and decision-making through new participatory procedures [41–45].

Currently, the green port concept applies a multicriteria context of port management as a tool [46]. Therefore, systems of environmental, social, economic and institutional indicators allow the monitoring and standardization of the concept of port sustainability. Performance indicators are closely related to the environmental dimension [47]; they must be quantifiable [48] and support planners' decision-making [49,50]. The particular study of social and economic externalities, such as port noise, discharges, climate change and/or water quality, is important [51,52].

2. Objectives

The purpose of this study is to present a descriptive and exploratory analysis based on a main research question: What is the epistemic social imaginary associated with the concepts of sustainable development and port authority in the mainstream literature? This question refers to the complex attributes of management, context, processes, standards and results. In addition, four specific objectives are proposed:

a) What are the main themes and attributes that emerge in the link between sustainable development and port authorities?
b) What are the main academic institutions that explore the role of port authorities and development?
c) How "emerging" and "opaque" is the relationship between sustainable development and port authorities?
d) What are the main epistemic consensuses at the academic level?

To answer these questions, a historical reconstruction methodology associated with a systematic review of the indexed literature in bibliometric databases is proposed.

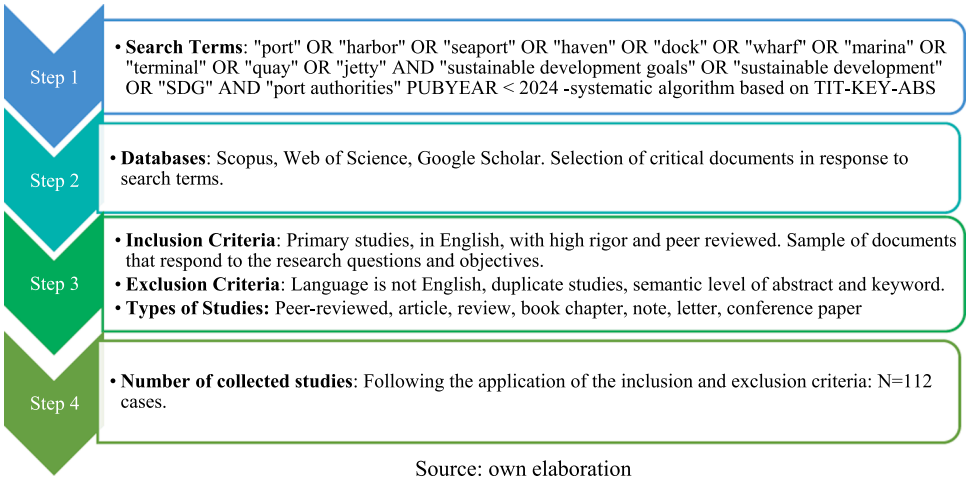
3. Methodology: the epistemic social imaginary

Rousseau et al. [53] note that bibliographic methods allow us to understand the productivity, distribution and evolution of a subject registered in various scientific fields. Van Ekc and Waltman [54] propose an open bibliometric program to search for significant attributes of publications that are related to a topic and/or contents of scientific knowledge. According to Seijo [55,56], a bibliometric analysis investigates the attributes and emerging consensus, in decline and/or currently relevant, of a scientific field projected on a systematic algorithm.

Fossile and Gouvea da Costa [57] affirm that a bibliometric method is systematic if it allows the following corollaries of data analysis: a) the study of the behavior of the literature of a scientific field; b) the measurement of the frequency of words and/or associated terms, according to Zipf's law; c) the evaluation of the productivity of authors, according to Lotka's law; d) the systematization of the productivity of journals, according to Bradford's law; e) the illustration of the behavioral pattern of a sample of documents and its attributes (authors, citation, productivity, community of practice, geographic evolution); and f) the synthesis of the problems associated with a set of attributes or bibliometric variables that give meaning to the evolution, development and state of the art of the subject.

There are many systematic analyses of bibliographic content. Such analyses follow the guidelines for critical analysis in the literature [29,58–61] and involve the selection of a study sample with which to conduct a historical, descriptive and evolutionary analysis or to reconstruct milestones in the relationship between concepts.

Weng et al. [62] argued that a review can be carried out with documents with certain keywords to analyze associated topics [63] or research issues [64],. Alamoush et al. [29] propose a complex algorithm to analyze the documents, authors and contents of a sample of the literature associated with ports, sustainable development and SDGs. Varese et al. [65] argue that the development of a systematic search



Source: own elaboration

Fig. 1. Methodological criteria for the selection of cases.

Table 2
Facets of the epistemic consensus in the study sample (N = 112).

Faces	Time frame with respect to N=112[a]	Ranking criteria	Attributes of the epistemic consensus
Emergence	2021–2023	-Second period of highest production and accumulation of citations-	- Evolution by country -Evolution by continents
Relevance	2010–2020	Period of the highest number of citations and greatest production -Consolidation of a community of practice-	-Ranking of authors -Ranking of magazines -Main institutions -Annual evolution of documents -Disciplinary evolution -Co-occurrence of lines of inquiry -Main concepts -Main adjectives -Epistemic consensus regarding themes
Opacity and/or abandonment	1999–2009	Initial period, with the least production and fewest citations	

[a] The criterion of grouping by decades is chosen in order to establish a minimum differential grouping between periods. This could be set differently at the discretion of the researchers [78].
Source: Own elaboration

algorithm (TITLE-ABS-KEY) allows the study of the art of sustainability [66]. Seijo [67] considers that it is possible to carry out macro- and microanalysis with an algorithm that starts from the field of systematic algorithms (Title or/and Keyword or/and Abstract). Other studies have proposed bibliometric reviews based on a specific database, Scopus [68–70], or analyses of document titles with different bases or samples of documents [71–73].

The case selection methodology follows the methodological recommendations of Garrido-Cardenas et al. [74], Dinić and Jevremov [75], Mongeon and Paul-Hus [76], who argue that Scopus offers broader coverage compared to Web of Science (WoS) and Google Scholar, being the optimal choice for implementing a systematic search algorithm-Title, Abstract and Keyword- and literature review. These authors also highlight that Scopus not only indexes a larger volume of peer-reviewed academic literature, but also maintains rigorous control over the citations included in its database, which significantly differentiates it from WoS and Google Scholar.

Fig. 1 shows the methodological procedure and outlines how the search algorithm is chosen. It presents the reasons for the case selection, the main semantic fields and the inclusion and exclusion criteria of the academic documents in the databases studied. The chosen algorithm is shown with the above methodological considerations.

The algorithm used yields a total of N = 112 documents. The most common concepts shown, including the main concept and synonyms, are associated with the subject under study: "port authority" and "sustainable development". We obtain an association that allows us to reference literature with a series of attributes and results supporting ad hoc analysis. These include the number of citations, authors and institutions or countries, and the main lines of research associated with clusters of co-occurring themes between authors.

The research process is complemented by the results obtained by two programs. The bibliometric visualization program VOSViewer version 1.6.13 allows the generation of a graph of co-occurring research lines and the grouping of the research lines by clusters. The Atlas Ti program is used to perform an analysis of the most recurrent concepts in the literature at the level of argumentation (according to the abstract of each document) and the adjectives most frequently used.

Table 3
Cycle of the epistemic imaginary in the relationship between port authorities and sustainability (N = 112).

Periods	Epistemic consensus (Nº citations)	No. of documents	Weight%	Type of imaginary/ epistemic consensus
1999–2009	225	11	11.9 %	Opacity/ Abandonment
2010–2020	1406	63	74.2 %	Relevance
2021–2023	264	38	13.9 %	Emergent
Grand total	1895	112	100 %	

Source: Own elaboration from critical case database and Scopus citations

Finally, the methodological process supports the mixing of two approaches. Specifically, a qualitative and quantitative interpretation is made of the attributes assigned to a systematic algorithm. To position the social imaginary according to the concept of "epistemic consensus", the total number of documents and the degree of epistemic consensus are understood to be reflected by the highest number of citations in relation to the time scale of a decade. Therefore, with these methodological steps, we are able to approximate the degree of agreement between groups and/or communities of practice that advance or devalue, or do not contribute to, the subject under study in a "social network" situation [77].

Table 2 outlines the qualitative criteria used to classify the sample documents into three periods of total production: relevance, emergence and opacity/ abandonment. It also shows the ranking criteria adopted to achieve a longitudinal distribution of the data over a decade.

Abrahamson [79] argues that the evolution of the production regarding a subject reveals whether the scientific field presents repetitive behavior, many or few reformulations, and whether it develops or not over time in a management fashion. This is what we call the evolution of the social imaginary of epistemic consensus in the mainstream literature, which is represented by the qualitative criteria in Table 2 and operationalized by the quantitative criteria in Table 3 for the entire study sample.

4. Results: main attributes

The main results of the study are grouped according to four conclusions based on the mainstream literature and three representative figures. We obtain six key elements in relation to the objectives and proposed methodology.

First, the key arguments of the main authors with the greatest follow-up are described. Second, the institutional framework with the greatest disciplinary follow-up and the types of research implemented are presented. Third, the main journals and documents that value sustainable management practices for port authorities are given. Fourth, the evolution of the related production and the status of the literature associated with port improvement are presented. Fifth, the state of emergence, abandonment and/or collapse of production is visualized in Fig. 3. Finally, we indicate which main concepts and adjectives support the arguments for improving the role of the port authority and achieving the objective of sustainability.

4.1. Main narratives and impacts

According to the main authors in this field, the main attributes regarding the vision of a positive role of the port authority consist of the

Table 4
Chronological evolution of the arguments of the main authors (N = 198) with the highest epistemic production (N = 3)[51]

Order	Lead Author	Year/s	Sustainability Measures	Other main authors
1	**Puig, M.** [47,80,82]	2015, 2014, 2016	Evaluation of the port authority, environmental performance indicators, environmental management system and priorities	Puig, M., Wooldridge, C., Casal, J., Darbra, RM, Segui, X. Quintieri, E.
1	**González Laxe et al.** [49,50,83],	2019, 2017, 2016	Synthetic multidimensional indices	Martín Bermúdez, F., Martín Palmero, F., Novo-Corti, I.
1	**Roberts, T.** [85,81,86]	2023, 2021a, 2021b	Anticipation of meteorological events, circular economy, communitarianism	Roberts, T., Williams, I., Preston, J., Odum, M., O'Gorman, S.

Source: Own elaboration according to N=122 documents

moments of change.

(5) *Multidimensional synthetic indices with an ecosystem approach.* This work, which was directed by González-Laxe and colleagues in 2019 [21, 83] and began in 2016 [49,50,84], argues that changes in port activity should entail "(…) a diagnosis of the evolution of port sustainability measured through the economic, institutional, environmental and social dimensions to be established, as well as a study of the patterns of behavior that each port has followed in this issue" (González- Laxe et al., [83], p. 491).

(6) *Democratic communication between the port and the city hosting the port facilities*. It is proposed that there should be more evidence of how to minimize the externalities created by ports for local residents [81,85].

(7) *Generation of corrective measures for externalities according to circular economy principles*. For Roberts et al. [86], this situation should involve placing resident citizens at the center of port management and generating sustainable reuse measures via a circular economy approach. In his opinion: "Ports can add additional economic benefits for the cities they are located in by encouraging maritime clusters, industrial development, a circular economy, and waterfront development" (Roberts et al., [86], p. 7079).

Table 5
Main institutions, disciplines and documents related to port sustainability (N = 112).

Rank	Main institutions (N = 160)	Weight (%)	Disciplines (N = 15)	Weight (%)	Document type (N = 4)	Weight (%)
1	**Delft University of Technology (8.9 %)**	8.9 %	**Environmental Science**	21.10 %	**Article**	58.9 %
2	**University of Southampton (8.9 %)**	8.9 %	**Engineering**	20.68 %	**Conference Paper**	32.7 %
3	**Shanghai Maritime University (8.9 %)**	8.9 %	**Social Sciences**	19.83 %	**Book Chapter**	4.7 %
4	**Maritime University of Szczecin (6.7 %)**	6.7 %	**Energy**	9.70 %	**Review**	2.8 %
5	**Polytechnic University of Catalonia (6.7 %)**	6.7 %	**Earth and Planetary Sciences**	8.02 %		
6	**University of Cantabria (6.7 %)**	6.7 %	**Computer science**	5.06 %		
7	**University of Coruña (6.7 %)**	6.7 %	**Agricultural and Biological Sciences**	3.80 %		
8	**Cardiff University (6.7 %)**	6.7 %	**Business, Management and Accounting**	3.80 %		
9	**The Bulgarian Academy of Sciences (6.7 %)**	6.7 %	**Economics, Econometrics and Finance**	2.95 %		
10	**Università degli Studi di Genova (6.7 %)**	6.7 %	**Arts and Humanities**	1.27 %		

Source: Own elaboration according to N=122 documents

following management–action proposals[4]:

(1) *Assessment of the importance of port authorities (tool to assist port authorities in identifying aspects and in assessing their significance)*. Puig et al. [47,80] reported low monitoring and control of the work of port authorities. In this field, there is a lack of control of externalities and a need for the standardization of environmental assessment methods.

(2) *Environmental performance indicators in port areas.* These indicators are used for the analysis of operational, administrative and environmental performance. They are used to support the change in the management of port authorities with the use of quantifiable indicators and evidence given in reports over time [80].

(3) *Evaluation of the state of response to extreme meteorological events*. The first results related to this aspect were produced in 2023, with a study on the priorities and solutions of the state of a port in 26 countries [81]. Port authorities must address contextual and local measures to mitigate climate change, water pollution, noise, waste and recycling.

(4) Improvement in the environmental performance and priority index. This idea, proposed by Segui et al. [82], refers to the measurement of compliance with the standards of an environmental management system and how ports at the European level may meet priorities at different

[4] Initially, we considered the main authors with the greatest production and follow-up. We explore the narratives that reveal and approximate some of the trends of change, consider how the transformation of a particular theme is observed, or not, and analyze how the contributions with many citations gain importance and intersect to from a community of practice of international literature [67]. The citations that are taken as a unit of measurement are referenced according to Scopus guidelines.

4.2. Main context: disciplines and institutions

Table 5 presents the institutional and disciplinary framework and type of research carried out regarding how evidence is visualized and steps for improvement are proposed for the management of port authorities in terms of sustainability. At the global level, the main institutions correspond to technology centers and/or universities with both the highest related research production and the most prolific authors.

Delft University of Technology, University of Southampton and Shanghai Maritime University rank first. Racking second are the Maritime University of Szczecin, Universitat Politécnica de Catalunya, University of Cantabria, Universidade da Coruña, Cardiff University, the Bulgarian Academy of Sciences, Università degli Studi di Genova, Polytechnic University of Madrid, Uniwersytet Szczecinski, the Port Authority of New York and New Jersey, and the Port Authority of Rotterdam. These 14 organizations, represented by 45 authors, contribute the most to the research. Other institutions have just 1 or 2 studies engaged in this field.

Regarding the main knowledge disciplines represented in the studies of the relationship between sustainability and the port authority, three fields stand out within a total of 15 disciplines or scientific fields. Specifically, environmental science is first, followed by engineering (2nd) and social sciences (3rd). In turn, examples of the main epistemic imaginaries of these disciplines are the following articles: "Environmental sustainability in seaports: a framework for successful innovation" (Environmental Science, 209 citations). "A framework for building a smart port and smart port index" (Engineering, 123 citations). "Towards Sustainable ASEAN Port Development: Challenges and

Table 6
Ranking of authors and journals with the highest consensus on port sustainability (N = 112).

Rank	Authors (N=107)	Title	Journal	Q	Country	Citations
1	Acciaro et al. [38])	Environmental sustainability in seaports: a framework for successful innovation	Maritime Policy and Management	Q1	United kingdom	209
2	Peris-Mora et al. [31])	Development of a system of indicators for sustainable port management	Marine Pollution Bulletin	Q1	United kingdom	180
3	Molavi et al. [87])	A framework for building a smart port and smart port index	International Journal of Sustainable Transportation	Q1	United kingdom	123
4	Puig et al. ([80])	Identification and selection of Environmental Performance Indicators for sustainable port development	Marine Pollution Bulletin	Q1	United kingdom	112
5	Di Vaio et al. [88]	Key performance indicators for developing environmentally sustainable and energy efficient ports: Evidence from Italy	Energy Policy	Q1	United kingdom	96
6	Martínez-Moya et al. [89]	Energy efficiency and CO2 emissions of port container terminal equipment: Evidence from the Port of Valencia	Energy Policy	Q1	United kingdom	91
7	Roh [40]	Toward Sustainable ASEAN Port Development: Challenges and Opportunities for Vietnamese Ports	Asian Journal of Shipping and Logistics	Q2	Netherlands	75
8	Lu et al. [90]	Examining sustainability performance at ports: port managers' perspectives on developing sustainable supply chains	Maritime Policy and Management	Q1	United kingdom	69
9	D'Amico [91]	Smart and sustainable logistics of Port cities: A framework for comprehending enabling factors, domains and goals	Sustainable Cities and Society	Q1	Netherlands	69
10	Hiranandani [92]	Sustainable development in seaports: A multicase study	WMU Journal of Maritime Affairs	Q3	Germany,	64

Source: Own elaboration according to N=122 documents

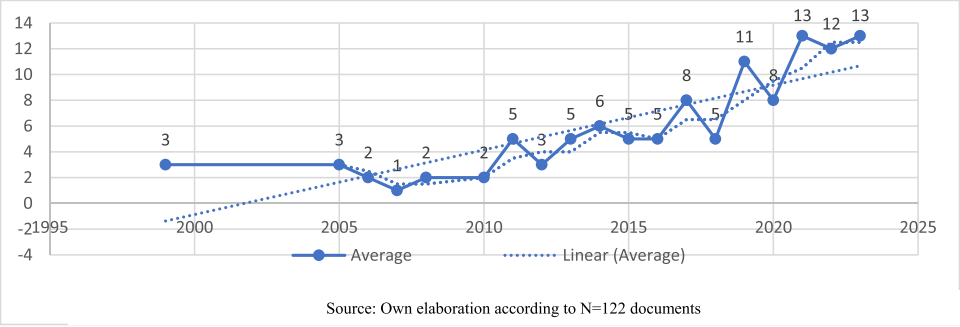


Fig. 2. Average evolution of research production regarding port sustainability (N = 112).

Opportunities for Vietnamese Ports" (Social Sciences, 75 citations). These studies highlight the need to increase knowledge about the ecosystem profile between the port authority and sustainability.

4.3. Main journals and authors according to epistemic consensus

Table 6 presents the distribution of journals with the greatest impact and the authors with a higher epistemic following in global production. Consequently, this journal ranking illustrates the criteria of greater scientific rigor and maximum scope, evidenced in quartile Q1.

Overall, most of the publishing journals, except for the two international journals of the Asian Journal of Shipping and Logistics (Q2) and WMU Journal of Maritime Affairs (Q3), had high impact.

The type of epistemic consensus, with respect to Table 6, is indicated by a higher number of citations. Consistently, it is divided into three levels for all communities of practice: high incidence (> 100 citations), medium incidence (between 100 and 80 citations) and low incidence (<80 citations).

In the first section, the themes of sustainability and the port authority were highly disseminated via two journals and three articles with greater consensus, specifically by the journals Maritime Policy and Management [38] and the Marine Pollution Bulletin [31,80], both belonging to the United Kingdom.

The high and medium incidence section is represented by two journals and three articles from the United Kingdom: The International Journal of Sustainable Transportation [87] and Energy Policy [88,89]. Finally, the low-incidence segment (<80 citations) is represented by a greater diversity of publications, four in total, from three countries (United Kingdom, Netherlands, Germany). In addition, the order of scope is distributed between a minimum of 64 and a maximum of 75 citations for the following journals: (1st) Asian Journal of Shipping and Logistics [40]; (2nd) Maritime Policy and Management [90]; (3rd) Sustainable Cities and Society [91], (4th) Journal of Maritime Affairs [92].

4.4. Evolution of production in the epistemic social imaginary

Fig. 2 presents the trend of publications in this community of practice and illustrates how related production presented a period of decline (2005–2019) and then a period of growth (2019–2023) following the initially stable situation of slow, sustained growth between 1999 and 2005, during which an average of three articles were published per year. This division into periods is based on Abrahamson's [79] methodology. Thereby, we confirm the existence of high variability in production. Seven U-shaped moments lead to a surge in global academic production in the last period and a decline in 2023.

On the other hand, Fig. 1 shows both variability and stability in the development of production and the proposals that are considered in the analysis of the data studied. Therefore, in a short period of time - a total of 24 years - a great diversity of proposals and evidence from a diverse community of practice is being built up - see Table 3 in connection with Figs. 2 and 3. This is deduced, in the first place, by the high variability of production -see the seven periods U shaped- and the very short period of production (1999–2023), given the socioeconomic relevance of the

[5] Authors with the highest number of papers, n=3, above a total of N=198 authors for the whole sample (N=112).

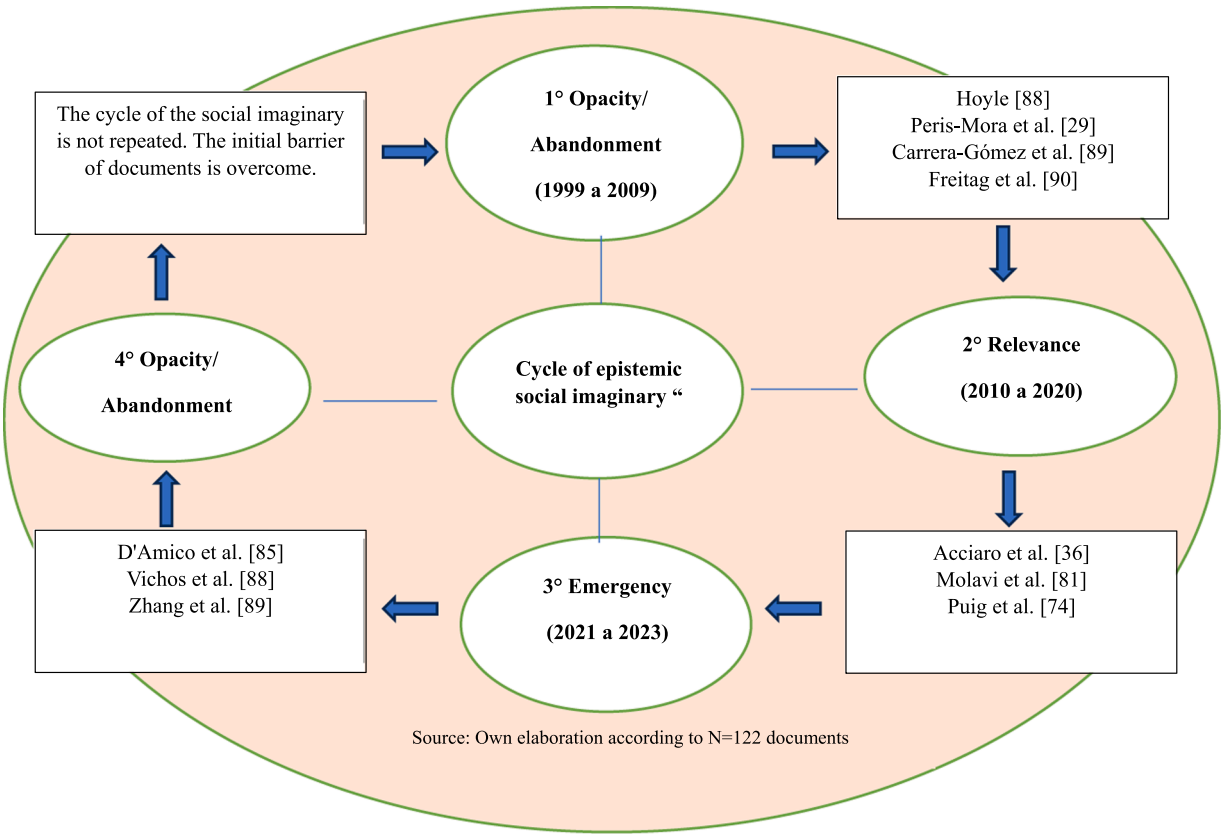


Fig. 3. Cycle of the epistemic social imaginary between the relationship between the port authority and sustainability (N = 112).

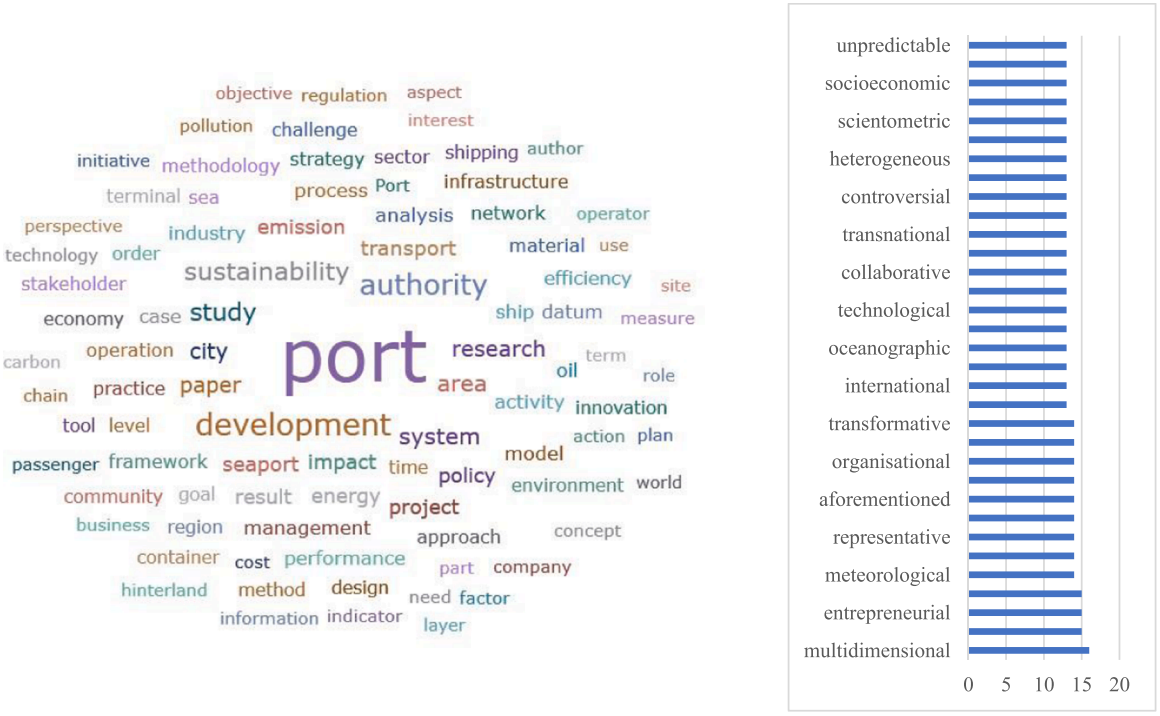


Fig. 4. Main concepts and commonly used adjectives in port sustainability research (N = 112).

study subject -"Ports and Sustenability"-for the world economy. Ports are the main entry points for goods and key sites for monitoring the state of economic prosperity. In fact, according to the United Nations Conference on Trade and Development [93], in 2019, it was estimated that global maritime trade represented more than 80 % of world trade by volume and more than 70 % by value. Seaports were also estimated to handle more than 11 billion tons of containerized cargo.

Finally, the academic literature that we study generates an epistemic

Table 7
Evolution of the main thematic consensuses in the governance of port authorities.

Rank	Year	Type of case-scale	Themes for improvement in the management of port authorities
10	2021	Global	Sustainability of logistics and digitization
4	2020	Global	Smart port index (SPI): market share competition and operational security
6	2019	Valencia	Energy efficiency and CO2 emissions: equipment
5	2018	Italy	Key performance indicators: environmental and energy regulation
7	2016	Vietnam-ASEAN*	Sustainable port development and sustainability agenda: environmental, social and economic factors
8	2016	Taiwan/ Global	Sustainable supply chains and type of sustainable management (external/internal)
1	2014	Europe/ Global	Environmental sustainability and successful innovations
3	2014	Europe/ Global	Environmental performance indicators (EPIs)
9	2014	Global	Policies and practices of sustainable port development: drivers and limitations
2	2005	Valencia/ Global	Environmental management indicator system: activities

* ASEAN is the Association of Southeast Asian Nations (1967)
Source: Own elaboration from according to N=122 documents

social imaginary in which the relationship between the port authority and main themes evolves through situations of emergence, relevance, and opacity or abandonment over time. In this sense, Fig. 3 identifies the three main contributions and the epistemic situation in relation to the study sample (N = 112), sorted it by time frame and highest number of citations.

Fig. 4 shows the key concepts of world production and the adjectives most commonly used with reference to the relationship between sustainability and the port authority.

Fig. 4 shows that, out of a total of 99 concepts, the main fields are associated with the improvement in sustainability in terms of the role, practice, strategy, evaluation of the situation and evidence of synchronous and asynchronous monitoring between the port, the port authority and sustainability.

Regarding the most commonly used adjectives, those used most frequently to qualify the relationship between sustainability and ports, among others, are the following: unpredictable, supranational, socio-economic, sociocultural and scientometric.

The results in Fig. 4 show a trend in which related research is increasing, despite periods of declining production. Several recurring themes are evidenced, including the discovery and analysis of contextual factors, the urgency of establishing long-term monitoring methods and indicators, and the incorporation of community participation at the center of port management. There are also themes presenting low annual production, with a minimum of 1 a proposal to a fashion of 2 to 13 articles (mean 5.83) every five years. This situation reveals the importance of emergence and adaptation of research directions that promote greater follow-up. In addtion, current production (N = 112, until 2023) has a low growth rate (4.68 %) and an annual average of 5.6 publications, with a production variability of 67 % over 24 years of accumulated experience.

5. Conclusions and lines of research

The results presented characterize how various paradigms related to the role and work of port authorities are interconnected. The scientific evidence confirms a positive and demonstrative change in administrative functions promoting an ecosystem approach to adaptive management in the port organizational environment.

In recent years, the motivations for change in port management have stemmed from the attention to the sustainability of port operations around the world and the idea that these facilities should be engines of organizational change. Other important aspects remain the public commitment to good governance regarding noise pollution, the difficulty of handling ships, sustainable development strategies and environmental repercussions in the work environments of importance to neighboring and distant human settlements.

Digital technologies are also shown to play a crucial role in optimizing port logistics and achieving sustainable development. Port authorities apply measures such as renewable energy, energy efficiency improvements and community participation to reduce the environmental impact of the unloading and handling of substances.

In addition, port operators conduct studies to evaluate the efficiency of port authorities, assess the impact of the oil industry in port cities and develop sustainable energy management systems. Collaboration between port and municipal authorities, as well as the reuse of heritage structures, are considered key strategies for achieving sustainability. In general, sustainable port development requires a multifaceted approach and the integration of environmental, social and economic considerations; this promotes the transition of the administrative functions of port authorities to adaptive management.

In accordance with the proposed objectives, a positive relationship is observed in four trends found in the study documents addressing the relationship between port sustainability and the role of port authorities. These trends are as follows:

First, for the main themes or attributes, as shown in Table 7, the port progress axis is manifested in the following ten milestones:

(1) Ensure environmental sustainability and successful innovation;

(2) Ensure that all activities of a port system comply with environmental management indicators;

(3) Establish a European framework of environmental performance for the measurement of achievements in the short, medium and long terms. Its repercussions are global, in order to anticipate and generate precautionary measures to avoid systematic damage;

(4) Attend to the security of port operations in accordance with market share competition and generate comprehensive mechanisms of measurable feedback indices;

(5) Regulate the performance in environmental and energy regulation and port practices;

(6) Update equipment to achieve low carbon emissions;

(7) Integrate key indicators with an ecosystem approach (environmental, social, economic);

(8) Balance supply chains;

(9) Redesign maritime port policy according to the drivers and limitations in practice and the political-administrative foresight; and

(10) Update functions according to measurable standards (digitization) and with logistics based on ecosystem sustainability.

Second, the main institutions with a community of practice, that is, with the largest number of interested scholars, are located in Spain and Europe. While a total of 160 port authorities are studied, academic researchers have given more attention to and developed a community of practice located in Europe and, more specifically, in Spain. In this sense, among the fourteen institutions with the most related scholars, four are Spanish: the Polytechnic University of Catalonia, University of Cantabria, University of Coruña, and Polytechnic University of Madrid.

Third. Research on the relationship between sustainable development and port authorities is emerging. A growth trend is detected, with a U-shaped evolution in the number of yearly publications, and the dynamics of production present an innovative and consolidating characteristic, despite incremental production, with the accumulation of knowledge and the development of a community of practice over two and a half decades.

Fourth, there is a worldwide epistemic consensus that associates sustainability with the change in management with regard to the role of the port authority. This trend, demonstrated in the results, implies the recognition of the important role of the port authority in the face of

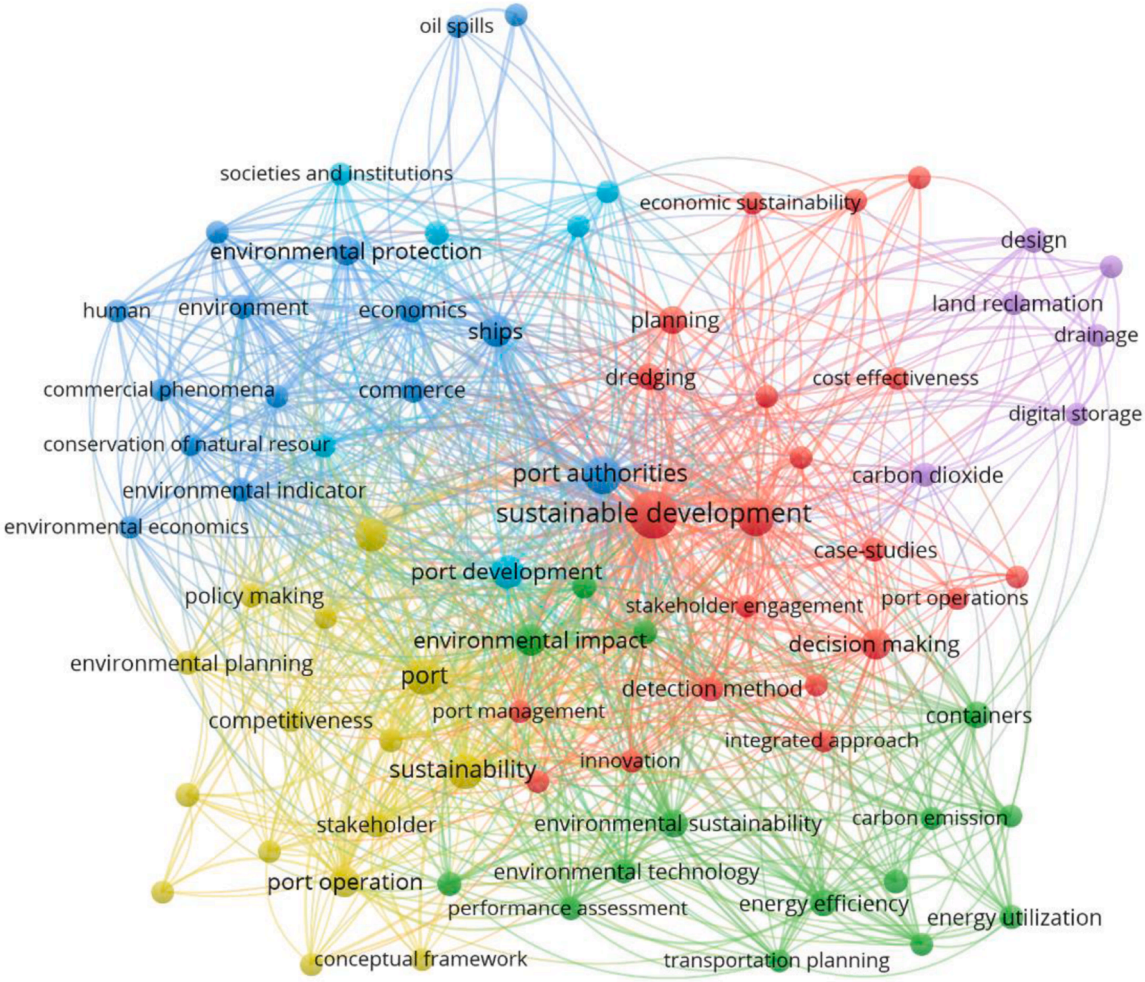


Fig. 5. Network of port sustainability issues (N = 112).

organizational challenges related to the ecological transition and transdisciplinary science.

In summary, the trend in the 21st century supports a new role for port authorities according to a new, transformative agenda with five axes of change:

a) Governance and style of public policy. This vision implies that port authorities adopt open government principles to generate a new participatory political culture and become less "parochial" in the so-called "black box" of political-administrative systems [21,94].

b) Change in working conditions. This axis implies rethinking the port space not only as a space permeated by the blue economy paradigm but also as a space exemplifying the concept of systemic equity, in which economies of scale are executed on the basis of the blue justice approach [95].

c) Monitoring and evaluation of the conditions between agents and the environment. For this purpose, it is key to address the OECD [96] diagnoses with public participation.

d) Generation of multiscale rationality processes. This vision is based on the mediation and collaborative rationality between interested parties. With the creation and reestablishment of a balanced ecosystem in the context of ports and negative externalities.

e) Processes of transformative change between the environment and the community regarding the main issues of demand and low supply. This implies restructuring the port space according to the international episteme that prioritizes action regarding the following main issues[6]: sustainability, environmental impact, pollution, environmental management, economic sustainability, environmental pollution, air pollution, sustainability parameters, water management, environmental challenges, biodiversity, environmental awareness, air quality, environmental conflicts, community involvement, social impact, stakeholder involvement, community, and social innovation.[7]

In contrast to the four trends in the role of port authorities and sustainability, international port management remains weakly addressed. At times, democracy is still overtaken by authoritarian regimes. The following question should be answered: how would Robert Dahl [97]respond according to his work Who Governs? The port decision-making process can become an opaque, refractory process that is distanced from the community where it is practiced when it is controlled by powerful interests in the face of the atomization and low capacity of resource mobilization among the majority of citizens.

Ultimately, the new approach to the role of the port must be based on overcoming the mechanistic vision of human resources. That is, high-

[6] These ideas were developed through the cases outlined according to the search algorithm shown in Section 3: Critical Case Methodology o so called: the epistemic social imaginary.

[7] These topics are the result of grouping the main documents according to their theme (as revealed in the abstracts and contents).

quality human capital [98] and social capital [99] must be integrated, despite the persistence of systemic asymmetries within contemporary management paradigms.

Finally, the most advanced lines of research concerning the role of the sustainability of port authorities, as shown in Fig. 5, consider five clusters of knowledge interaction. These lines of research, in which the epistemic debate is manifested, visualize a community of practice and respond to the debate of ideas that are exemplified by the following belief systems (clusters):

Cluster 1: Benchmarking, carbon emission, carbon footprint, competition, containers, cost effectiveness, emission control, energy efficiency, energy utilization, environmental impact, environmental regulation, and environmental sustainability.

Cluster 2: Commerce, commercial phenomena, competitiveness, conservation of nature, economics, the environment, environmental economics, environmental performance, environmental protection, models, oil spills, planning, and shore protection.

Cluster 3: Coastal zone management, dredging, environmental indicators, environmental management, environmental monitoring, policy-making, risk assessment, risk management, societies and institutions, stakeholders, and sustainable development.

Cluster 4: Case studies, decision-making, detection methods, economic sustainability, innovation, integrated approaches, investments, stakeholder engagement, strategic approaches, and strategic planning.

Cluster 5: Carbon dioxide, design, construction, digital storage, drainage, and land reclamation.

In summary, port authorities face a complex task in seeking to achieve harmony according to the concept of sustainable development. The grouping of themes, or clusters, underscores this dynamic of interaction and reveals clear distinctions between environmental, social and economic governance. The most rigorous studies underline the central importance of the port authority as a "policy-maker" that exercises a transformative role in the port ecosystem. This implies facilitating, evaluating and inducing commitments and processes between authorities, citizens, public administrations and environmental practices. Moreover, it supports transformative change of practices, values, and structures regarding the set of energy issues (Cluster 1), environmental management (Cluster 2), monitoring and policy measures (Cluster 3), planning (Cluster 4) and the carbon footprint (Cluster 5).

Finally, we consider that this study could be extended with a thematic and content analysis of the sample analysed, as well as generating complementary inferences under a micro-macro relationship on the epistemic lines and attributes developed.

CRediT authorship contribution statement

Federico Martín-Bermúdez: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Javier Seijo-Villamizar:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Fernando González-Laxe:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare no conflicts of interest

Acknowledgments

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2024.106491.

Data Availability

Data will be made available on request.

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