

Promoting Sustainability through Assessment and Measurement of Port Externalities: A Systematic Literature Review and Future Research Paths

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Abstract: In an attempt to mitigate and balance economic, environmental, and societal externalities that ports exert, port sustainability is becoming increasingly important as a key priority. This work embarks on an effort to explore the boundaries, provide a holistic view, and establish a knowledge map of contemporary research in the field of port externalities and impacts, by conducting a systematic literature review (SLR) by carrying out a three-stage procedure (planning, execution, and reporting), enhancing objectivity, while limiting errors and bias. The literature under study pertains to research domains focusing on: (a) identifying port externalities and impacts, (b) utilizing metrics and indicators to measure and quantify the positive or negative impact of port externalities, and (c) promoting an inclusive framework for sustainable port development. Our results include, among others, the classification of methodologies and particularly, of indicators established per type of externality to measure and monitor sustainable port performance, as well as identification of trends and gaps within the contemporary literature. We find considerable room for exploring new concepts and research paths within the domain of port impacts and externalities, both within individual dimensions of sustainability (economic, social, environmental), and on a multidisciplinary level.

Keywords: port externalities; sustainability; SLR; port indicators and metrics; meta-analysis

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1. Introduction

The role of ports as engines for local, regional, and national growth [1–3], as well as their capacity in reflecting economic activity [4], is widely acknowledged within contemporary literature. Despite their significance in economic development, trade facilitation, and employment [5,6], adverse negative externalities of port operations and development on the environment and, in extension, on society, have become an ever-growing concern for seaport organizations [7]. Thus, while many ports strive to “go green” through integration and adoption of proactive measures and practices aiming at mitigating their environmental footprint [8], expectations of their users and stakeholders are increasingly focusing on a more comprehensive and holistic approach, to establish a balance between economic, environmental, and societal interests. In this context, the concept of port sustainability emerges as a novel alternative approach to traditional port management strategies, aiming to provide an inclusive and enhanced framework for monitoring the management of the exerted positive and negative externalities of ports [9]. According to the definition of PIANC [10], a sustainable port is one in which the port authority, together with port users, proactively and responsibly adopts a green growth strategy and promotes stakeholder participation in mapping the long-term vision in a manner that ensures that port development meets the contemporary needs of the region it serves, without compromising the ability of future generations to meet their own needs.

Thus, within the sustainability framework comprised by the economic, environmental, and social dimensions, often referred to as the triple bottom line of sustainability [11], ports aim to enhance efficiency and performance and, hence, their competitiveness and economic impact to the wider economy. At the same time, ports are adopting a more active social approach to local communities and a more robust environmental management, abiding to regulations [12,13]. Lu et al. [14] argued that there is almost no unequivocal measure or criteria for either promoting or assessing sustainable development in ports while considering the triple bottom line dimensions; notwithstanding, a decade later, a novel and growing body of academic literature on the subject has started to emerge. The increase in the volume of published research in relation to exerted port externalities denotes the significance of conducting high-quality reviews that allow researchers, on the one hand, to effectively orient themselves within the paths of accumulated knowledge, while identifying research trends and developments. Furthermore, the heterogeneity of design and scope of available port studies often adds to the complexity of evidence and conclusion synthesis [15].

However, despite the rapidly growing popularity of this methodology in maritime and port literature [16–20], to the best of our knowledge, apart from the work of Lim et al. [21], which is based on a very specific sample of 21 papers on sustainability performance, a more holistic, comprehensive, and systematic review of literature with respect to measurement of the multi-dimensional exerted port externalities (positive and negative ones) has not yet been conducted. Previous reviews, such as Sislian et al. [12] on the integration of port sustainability measures in the ocean's carrier network problem, Davarzani et al. [8] on green ports and maritime logistics, as well as Dooms et al. [22] on socio-economic impacts of ports, can be considered narrow in scope, considering the research developments in recent years [23]. In the literature we review in this work, the focus is shifted towards the mitigation of externalities and maximization of positive impacts through the adoption and implementation of sustainable port strategies. In this context, numerous academic studies have focused on the measurement and quantification of a single dimension, or a combination of dimensions of port externalities. As such, the expanse in literature on the subject necessitates an in-depth investigation, in an effort to concentrate and classify, in an organized way, accumulated existing knowledge and state-of-the-art literature on port externalities in an effort to gauge and map, through a systematic literature review (SLR), the major aspects, measures, and methodological tools designed and implemented to identify, measure, and monitor and manage externalities.

Based on the above, we formulate the following set of research questions: Which are the major trends and developments within the port literature on port externalities and impacts? Does the literature adopt a holistic and inclusive sustainability perspective about assessing externalities, or does it treat them in isolation? What are the most prominent methodologies and how can they be classified? What are the gaps within the literature that are also the future challenges and fields of research? To answer those questions, we conduct a systematic literature review in three stages, starting with 542 papers, and by gradually constraining our scope, continue with 189 and finalize our review sample at 71 papers. Even though this research area can be considered quite active, due to the sheer research diversity of the individual dimensions of sustainability, we find considerable ground for further research, for which we will be elaborating upon in the following sections.

The remainder of this paper is structured as follows: In Section 2, we describe the methodology of choice; in Section 3, we perform the SLR and in Section 4, we discuss the results per sustainability dimension (economic, social, environmental, and multidimensional). Section 5 concludes the paper and proposes future research paths.

2. Methodology

Considering the wide scope of port externalities as a subject, necessitating analysis and classification of a large body of literature, as well as critical selection, appraisal, and

synthesis of findings [24], this exercise attempts, through the implementation of a systematic literature review (SLR), to explore the boundaries of literature, provide a holistic view, and establish a knowledge map of existing research [25].

According to the definition from Fink [26], SLR is a systematic, explicit, comprehensive, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work made by researchers, scholars, and practitioners. Unlike traditional literature reviews, which can be non-structured, non-systematic, or non-transparent, and with a higher level of subjectivity in data collection interpretation [27], SLRs follow a pre-defined process to analyse published literature in a reproducible and transparent manner so that results are more objective and less vulnerable to error and bias [28]. To this end, high-quality SLRs are valuable in informing policy and supporting practice [29]. Our study follows closely Tranfield et al. [28] by carrying out a three-stage procedure (planning, execution, and reporting), enhancing objectivity, while limiting errors and bias.

The basis for the review is an assortment of academic literature accessed through Google Scholar and Web of Science (WoS) databases between 12.2020 and 02.2021. As the aim of this first stage was to extensively cover the subject matter under study, as well as to attain the highest number of relevant literature papers, no initial inclusion and exclusion selection criteria were imposed in this stage.

In the execution stage, in order to obtain relevant bibliography from the databases of choice, a keyword search using multiple different strings was conducted. The structured keywords as per Munim et al. [17] utilized a Boolean function, comprising two parts. The first part (“positive” OR “negative” AND “externalities”, OR “sustainability” AND “measurement” OR “evaluation” OR “triple bottom analysis” OR “indicators”) captured relevant studies on externalities and sustainability while the second part (“port” OR “seaport” OR “hub port” OR “container port” OR “cruise port” OR “bulk port” OR “terminal”) focused on studies on externalities and sustainability within the port sector. All possible combinations of the above keywords were undertaken. In addition, while keeping the second part of the keywords, queries addressing particular externalities—dimensions of sustainability such as the economic (“economic externalities” AND “local” OR “regional” OR “national” AND “impact” OR “contribution” OR “effects” OR “measurement” OR “evaluation” OR “importance” OR “assessment”), the environmental (“environmental” OR “green” AND “externalities” OR “sustainability” AND “measurement” OR “evaluation” OR “assessment”) and the social (“social” OR “societal” AND “positive” OR “negative” AND “externalities” AND “measurement” OR “evaluation” OR “assessment”)—were performed.

As seen from the keywords above, we chose not to include explicit reference of keywords pertaining to port governance. Despite that port governance is one of the most extensive and active topics in port literature, and our scope of work is focused on identification of port externalities and impacts, metrics, and indicators; notwithstanding, the dimension of port governance is included in the discussion of our results.

Finally, the reference sections of studies obtained through the above queries, as well as the studies citing them, were thoroughly researched iteratively, in order to reduce the possibility of omitting important literature. As a result of the above process, 85 queries were undertaken, leading to an initial sample of 542 potentially relevant studies for consideration. Finally, to ensure, that the assembled papers extensively cover the subject under consideration, the same 85 queries were also performed in the SCOPUS database to investigate whether additional academic studies had been omitted from the initial sample. However, no additional results occurred. To enhance the sampling reliability and maintaining our focused scope, a set of exclusion/inclusion criteria were established: (i) conference papers, books, Ph.D. dissertations, reports, (ii) non-English papers, and (iii) non-accessible papers were excluded. Additionally, since the timeframe of the initial sample spanned from 1988 to 2021, the time frame of the review was constrained, by excluding all published studies prior to 2000. We then performed a screening for relevance of the

abstracts and keywords of the remaining 395 papers. Thus, any paper whose scope extended beyond the port industry's exerted externalities was discarded. During this process, 206 papers pertaining, amongst others, to the fields of maritime industry, maritime logistics, marine biology, green logistics and supply chain management, inter-modality, transport, dry ports, port performance, and efficiency were also discarded.

Subsequently, the remaining 189 papers were studied in detail, in order to distinguish papers addressing port externalities and sustainability through metrics, indicators, and measurements, from more generic/descriptive ones. Through this final filtering, 71 academic papers were chosen for our bibliometric meta-analysis. These papers were classified according to: (i) author(s), (ii) year of publication, (iii) journal, (iv) keywords, (v) citations obtained, (vi) paper type, (vii) methodological approach, (viii) type of externality addressed (i.e., economic, environmental, societal, multidisciplinary), and (ix) externalities addressed or measured in particular. The path towards our final sample is depicted in Figure 1 below.

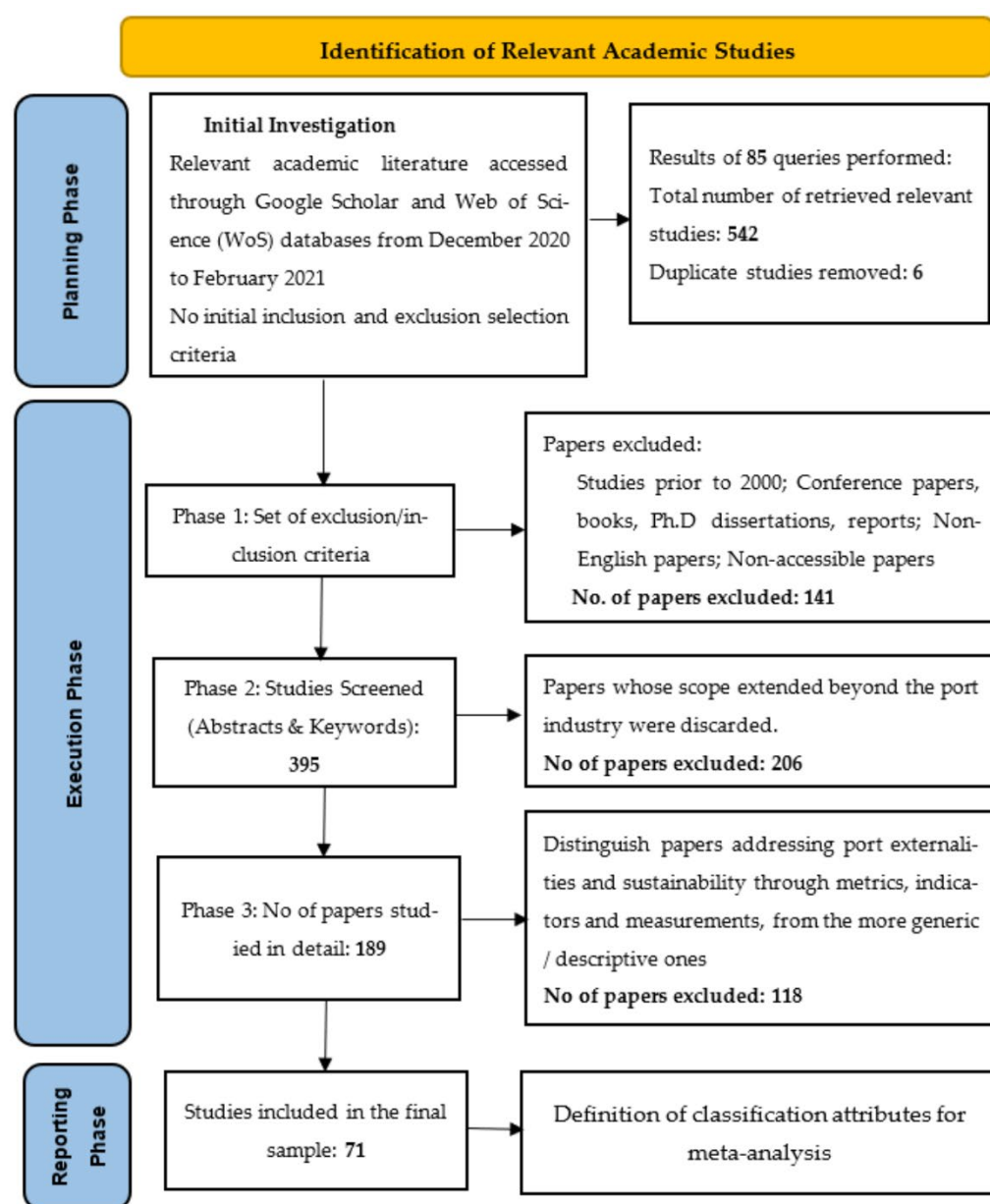


Figure 1. Main methodological steps of research design (based on Tranfield [28], Authors' elaboration, 2022).

3. SLR Results—Key Quantitative Data

In line with our research questions, in this section, the most significant quantitative results of the SLR are outlined. The chronological distribution of the 71 papers of our final sample is presented in Figure 2. As such, 21 papers are included in the first 15 years, representing 29.5% of our sample, in contrast with 50 publications (70.5%) over the last 7 years.

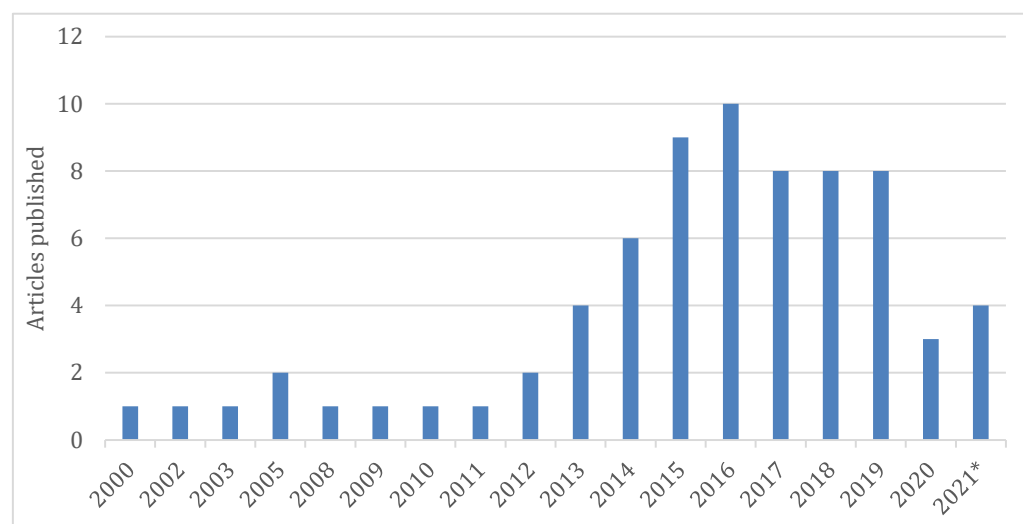


Figure 2. Chronological distribution of the sample papers (2021*: papers published until February 2021), (source: Authors' Elaboration, 2022).

Despite a decrease in the last one and a half years, between the 2015 and 2019 (60.6%) interval, a spike in the relevant published papers was recorded. As such, the distribution of papers within the timeframe under study indicates a growing attention of scholars within the port academic literature on the topic.

Our final sample includes 215 authors, with the overwhelming majority of the studies being multi-authored papers (97.2%) and only two being single-authored (2.8%). We also observe that 12.1% (26) of the authors published more than one article, and 176 authors appear only once in our sample. Table 1 depicts the most prominent authors in the research domain of port externalities and sustainability, based on the number of published papers. Furthermore, 20 authors published more than one relevant paper. Multi-authorship data, as presented in Figure 3, created with the VOSviewer © software, v.1.16.18, sourced from <https://www.vosviewer.com>, Leiden, The Netherlands [30], illustrate a limited number of co-authorships with more than one collaborative paper within our sample.

Table 1. Most prominent authors.

Author	Published Papers
Rosa Mari Darbra	5
Chris Wooldridge	4
Claudio Ferrari	4
Young-Joon Seo	4
Martí Puig	4
Jin Suk Park	3

(Source: Authors' Elaboration, 2022).

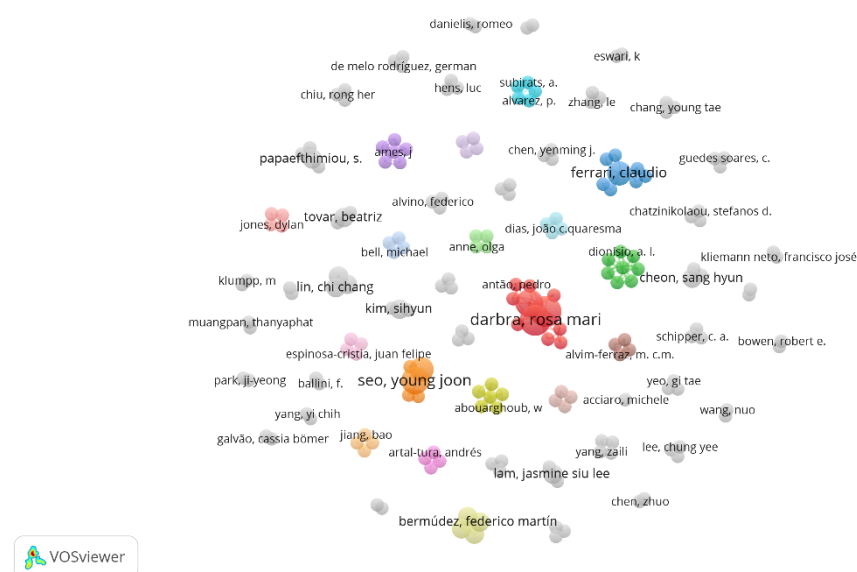


Figure 3. Major collaborations amongst authors (source: Authors' Elaboration in VOSviewer ©, 2022).

Although the papers in our sample were classified based on keywords, the derived results were highly diversified, visible both in Table 2 and Figure 4. Amongst the 34 keywords recorded occurring more than once in our sample, Table 2, below, presents the 10 with the highest frequency. Of these, the three most frequent keywords are industry specific (i.e., port industry related), followed by the keyword sustainability, which takes the fourth position in number of occurrences and represents the major research topic of reference. Despite its significance in the treatment of externalities, sustainability-related keywords are not as frequently utilized as expected by authors. In contrast, keywords relating to sub-components of sustainability, such as environmental and economic ones, although they have a slightly lower number of occurrences, represent 40% of the entries. Overall, the high degree of keyword diversification signifies that the research topic under study has numerous substrates and research streams. Furthermore, as suggested from Figure 4, also created with the VOSviewer © software, combining port- and sustainability-related keywords is a relatively recent development.

Table 2. Keyword classification and number of occurrences.

Position	Keyword	Occurrences
1	Port	14
2	Port management	7
3	Seaports	6
4	Sustainability	5
5	Environmental Performance Indicators	4
6	Input–output analysis	4
7	Sustainable development	4
8	Ship emissions	4
9	Economic growth	4
10	Environmental management	4

(Source: Authors' Elaboration, 2022).

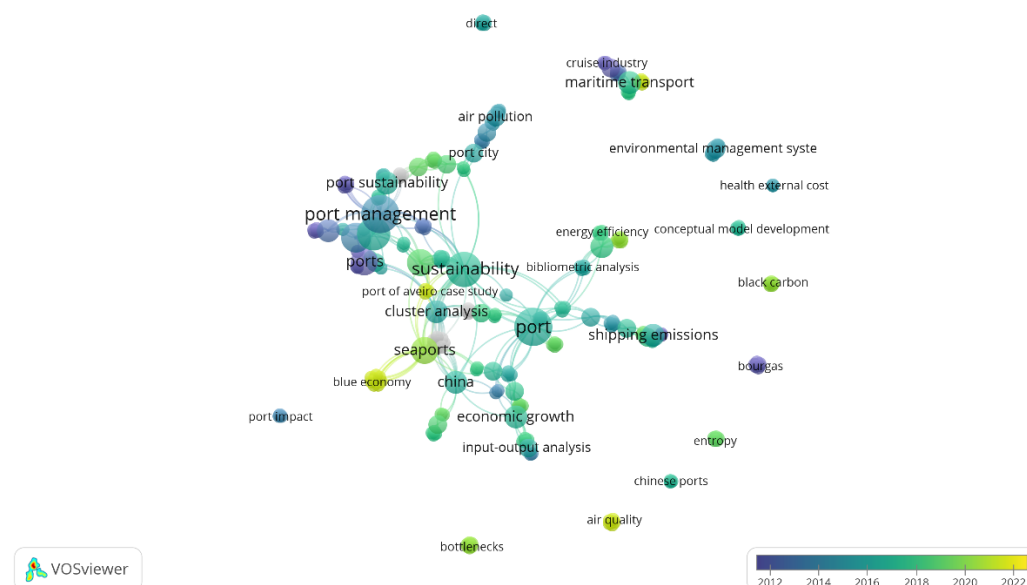


Figure 4. Historical evolution of keywords (source: Authors' Elaboration in VOSviewer ©, 2022).

The 71 papers in our final sample were published in 39 academic journals. Amongst those journals, 11 journals published more than one paper. Table 3 presents the number of papers per major academic journal, where we observe that apart from journals specializing in the transport and port sector, sustainable management of externalities of ports is a theme also included in environmental management and sustainability journals.

Table 3. Major journals included in the final sample.

Academic Journal	Published Papers
Maritime Policy & Management	7
Marine Pollution Bulletin	7
Transportation Research Part D: Transport and Environment	5
Ocean & Coastal Management	5
Transport Policy	4
Transportation Research Part E: Logistics and Transportation Review	4
Maritime Economics & Logistics	3
Journal of Environmental Management	2
Sustainability	2
The Asian Journal of Shipping and Logistics	2
International Journal of Transport Economics	2

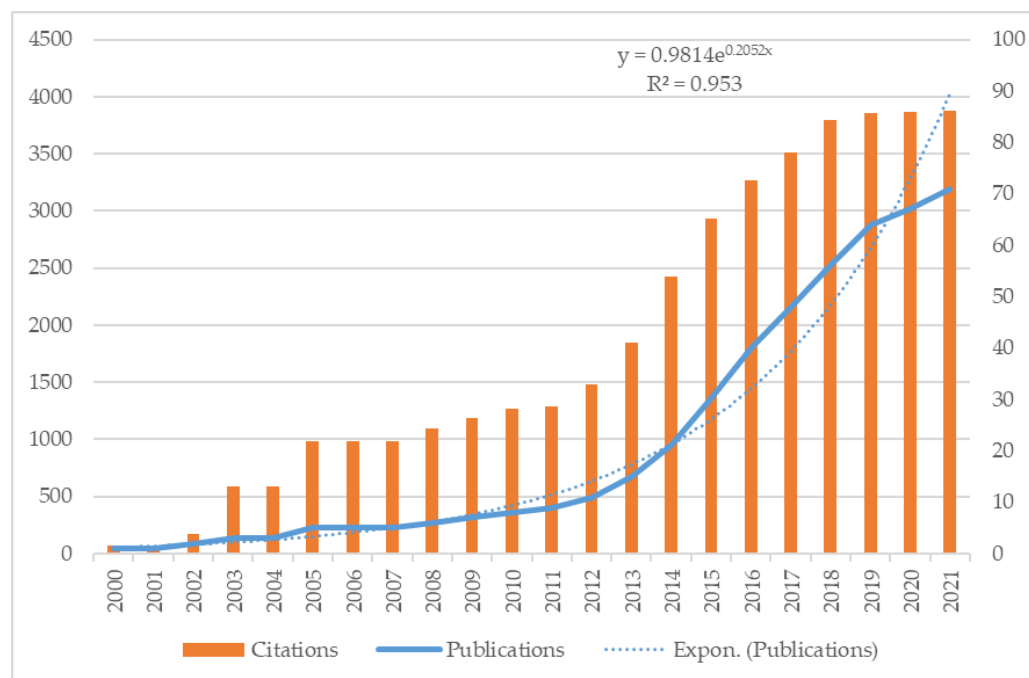
(Source: Authors' Elaboration, 2022).

Citations are suitable as a metric to capture the popularity and importance of the papers. Table 4 captures the number of citations from the Google Scholar database, as well as the local citations, i.e., the number of citations of the papers included in the table included within our total sample of 71 papers. It is interesting to note that the majority of the papers in Table 4 focus on environmental externalities and economic–environmental issues. The momentum of the relevant research is captured in Figure 5, with cumulative citations following an exponential rate of growth.

Table 4. Most cited papers.

Author(s)	Global Citations *	Local Citations **
(Bowen & Riley, 2003) [31]	412	1
(Peris-Mora, et al., 2005) [32]	253	17
(Berechman & Tseng, 2012) [33]	156	9
(Darbra, et al., 2005) [34]	139	4
(Puig et al., 2014) [34]	126	11
(Bottasso, et al., 2013) [35]	123	5
(Acciaro, 2008) [36]	117	7
(Maragkogianni & Papaefthimiou, 2015) [37]	114	6
(Yap & Lam, 2013) [38]	111	4

(*) Global citation: Google Scholar citations; (**) Local citation: number of citations within the sample of 71 papers (source: Authors' Elaboration, 2022).

**Figure 5.** Cumulative publications and citations (source: Authors' Elaboration, 2022).

The variety and diversity of methodologies utilized in the papers in our final sample are presented in Figure 6. On many occasions, more than one methodology is utilized in each paper. The most common methods (the 'Other' category includes methodologies utilized only once, such as: Cost Benefit Analysis, Stakeholder Analysis, Benchmarking, Delphi Method, and Multiple Criteria Decision Making, among others) utilized include indicator analysis, econometric analysis, DEA/AHP, and factor analysis.

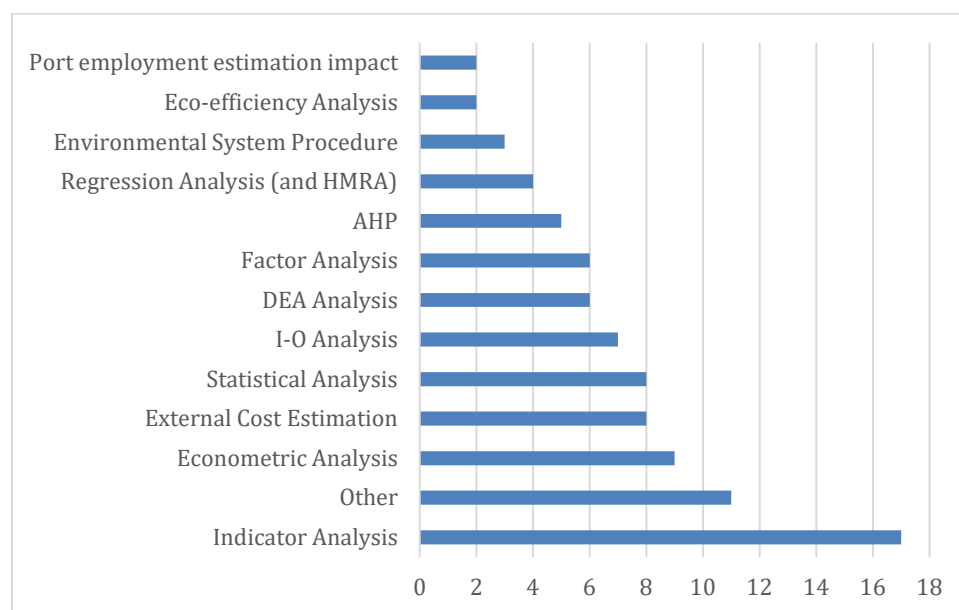


Figure 6. Categorization of methodologies utilized (source: Authors' Elaboration, 2022).

We categorize our sample based on the so-called triple bottom line concept [11]. In addition to the three dimensions of externalities (economic, social, environmental), we include conglomerated categories of socio-environmental, socio-economic, economic–environmental, and economic–social–environmental studies, in an effort to capture the overlaps between dimensions. Figure 7 outlines these overlaps in a quantitative manner.

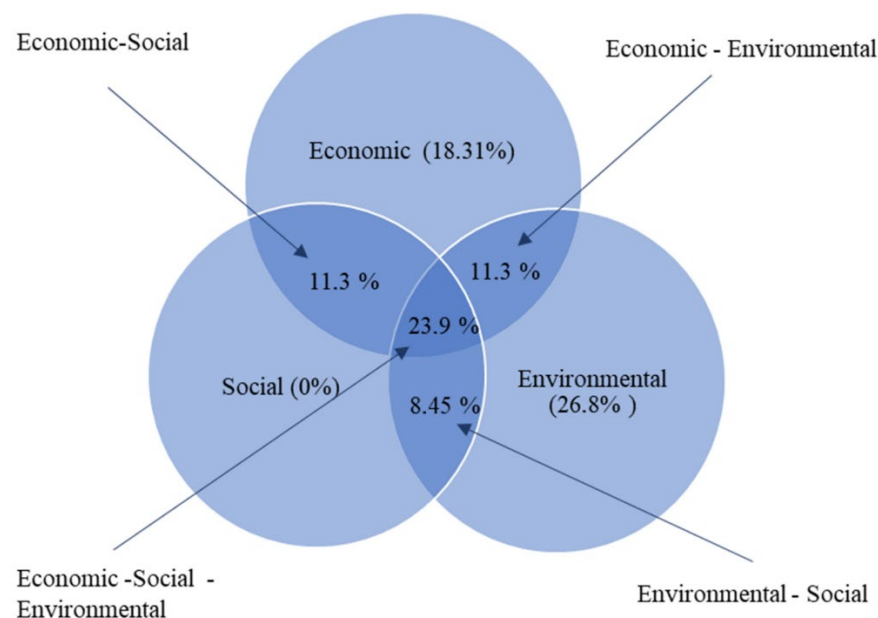


Figure 7. Categorization of papers per type of externality addressed (source: Authors Elaboration, 2022).

We observe that the environmental dimension of externalities attracts the most interest in our sample. More particularly, apart from 19 papers that deal exclusively with environmental issues in ports, there are additionally another 8 and 6 studies, respectively, within the economic–environmental and socio-environmental dimensions. By adding 17 papers, which adopt a triple bottom line approach, the environmental aspects are represented by, in total, 70.4% of the papers in our sample. Of the remaining studies, 13 papers

focus on the economic impact of ports and 8 adopt a socio-economic approach. None of the papers within our sample address solely the issues of social externalities for ports.

Finally, in Table 5, we classify indicators, per externality dimension, included in 17 papers that focus on metrics, indices, and composite indicators. Overall, we identify 26 distinct indicator categories, amounting to a total of 225 indicators and synthetic indices. The majority of indicators is concentrated in the environmental dimension (40%). Within this dimension, most of the indicators relate to the measurement and assessment of air quality (17), waste management (13), sediments (12), and soil (11) quality in ports. This is a clear indication that measurement of environmental effects is considered as a focus area, outlining ways for ports to address negative environmental externalities and improve their environmental performance.

Table 5. Classification of indicators per externality/impact type.

Type of Externality	Identified Indicator Categories	# of Indicators	# of Papers	% of 17 Papers
Triple Bottom line (6 indices)	Synthetic/Composite Sustainability Indices	6	6	35
	Air quality/pollution/emissions	17	11	65
Environmental Indicators (90 indicators)	Water quality/pollution condition	9	10	59
	Terrestrial habitats and Marine ecosystems	9	7	41
	Waste management	13	8	47
	Energy consumption	6	9	53
	Sediment quality and pollution	12	7	41
	Noise	2	7	41
	Soil quality	11	5	29
	Water consumption	5	4	24
	Environmental training	6	5	29
	Occupational health	21	6	35
Social Indicators (79 indicators)	Occupational safety	10	3	18
	Employment	11	5	29
	Education and training	12	5	29
	Human-rights-fairness (Gender Equality, Labour Structure)	4	3	18
	Security	12	1	6
	Urbanization	5	4	24
	Well-Being	4	2	12
Economic Indicators (59 indicators)	Added value generated	4	5	29
	Productivity and production capacity	15	4	24
	Economic and financial ind.	17	5	29
	Investments	15	5	29

Service Levels	5	5	29
R&D, port-city inter-face	3	4	18

(Source: Authors' Elaboration, 2022).

4. Discussion of the Results

4.1. On the Dimensions of Port Impacts and Externalities

In an attempt to identify research trends and gaps, in this section, we assess qualitative and quantitative trends for each major sustainability dimension (economic, social, environmental). Since the assignment of most papers into a sole dimension is less than straightforward, we also create composite categories (i.e., socio-environmental, economic–social) in order to capture the scope of each paper in a proper manner. We structure the following sub-sections accordingly.

4.2. Economic and Socio-Economic Impacts and Externalities

Measuring the amount of positive economic and economic/social impact of port development and operation on, among others, port cities, port hinterland, local, regional, and national economies has always been sought by policy makers, as well as practitioners, such as consultants supporting the former. Therefore, exploring ways and methods of capturing the economic effect of ports within a shifting environment shaped by the world trade conditions, regional and geopolitical priorities, shipping technology, and other factors have been popular subjects in contemporary literature [39–41]. An example of a national port indicator based on the Industrial Production: Manufacturing index, is elaborated in Angelopoulos [42]. The subset of our sample capturing economic and economic/social effects comprised 21 quantitative studies, spanning from 2000 to 2020, as well as one literature review, not included in our final sample, with 48.9 citations on average and 6.6 citations per paper annually. Despite some exceptions, which we will elaborate further, capturing the economic effect of ports can be considered a mature field, albeit with a limited scope, compared to multi-disciplinary studies.

More than half (55%) of the papers in our sample attempt to capture the impact or benefit of a specific economic factor, or a group of factors, with the majority [6,35,43–45] focusing on employment, a subject of elevated interest when considering transport infrastructure, while others [46–48] concentrate on impacts from local and regional development. With the exception of [47], there is a consensus on the positive role of ports in creating value added, both in terms of employment and economic development. It is interesting to note that only a few of the studies incorporate additional dimensions and links to the port sector, such as Munim and Schramm [48] with logistics and trade, and Park et al. [49] where maritime, land, and air transportation are covered.

Focusing on methodologies utilized, more than a third of our sample—for example, Braun et al. [50] and Chang et al. [51]—capture the economic impact of ports with variants of Input/Output (I-O) analysis, a method applicable to many sectors, that despite its static nature and reliance on subjective assumptions, is nevertheless a familiar tool to policy makers. Another third of our sample incorporates econometric methods and models, such as Park and Seo [52] where a Solow model is utilized, and Han et al. [46] utilizing the Cobb–Douglas production function. Despite the overall diversification of methodologies, we observe that economic/financial indicators have a comparatively higher level of standardization, as opposed to other indicator categories.

With respect to the trend and direction of future research warranted by our sample of papers and noting that one paper may include more than one future research item, we find that (a) further case studies, (b) hinterland/regional aspects, and (c) further elaboration on the scope and methodologies are the most frequent, equally represented by approximately a quarter each of our sample. Furthermore, in 14% of the papers, no future

research was recommended. The less represented item for future research is port governance, albeit present in the most influential paper of our sample [35], as well as Cheon et al. [53]. Important future research aspects, apart from port governance, that appear to be under-represented are logistics, road, and rail transportation and the role of ports as part of the supply chain. Finally, we find that case studies pertaining to individual ports tend not to focus on adverse implications of port development.

4.3. Environmental Externalities

The degradation of the natural environment caused by intensive economic activity has progressively risen awareness over the issue of climate change, both on a governmental and societal level. In the port industry, while ports have been proven to be vital to economic growth [52] in their surrounding areas, related ship traffic, handling of cargo, and hinterland transportation can simultaneously incur multiple negative impacts [54], both within the port areas as well as in their surrounding vicinities. More particularly, depending on their size, on the markets they serve, and on the multitude of services offered to port users, ports can contribute disproportionately to the pollution of the marine and terrestrial environment, as well as to the degradation of air quality [55].

In this context, an increasing strand in academic literature addresses the issue of port environmental externalities and proposes measures and strategies in an effort to minimize environmental footprint and enhance the environmental sustainability of port activities [56–59]. While the identification of an appropriate approach to green port management [60] is considered a challenge [16], the development and utilization of environmental indicators as relevant management tools to tackle negative environmental externalities is gaining ground [34,61,62]. Thus, many authors have so far utilized or constructed specific indicators to measure environmental performance of various day-to-day port activities and their impacts [63]. More specifically, with air and water pollution being considered the most prevalent side-effects of port operations [64], particular focus within the literature has been given in (a) measuring and monitoring air quality, in particular through estimating in-port ship manoeuvring or at hoteling-related emissions [65,66], and (b) water quality and its effects on the preservation of marine ecosystems [67,68]. Additionally, numerous environmental indicators have been developed to measure other potentially environmentally harmful aspects of port operations, such as noise emissions, (hazardous) waste management, energy consumption, dredging operations, and soil and sediment pollution [32,34,69–74].

Apart from the identification, quantification, and measurement of negative externalities, utilization of environmental indicators provides the means for port authorities to evaluate environmental performance, promote more sustainable management, and monitor progress towards continuous improvement [75]. Due to their usefulness and their practical application, Puig et al. [60,61] developed a method (tool for the identification and assessment of environmental aspects in ports—TEAP) that facilitates the identification of port indicators in a more reliable manner, as well as a complementary tool for environmental indicators in ports (TEIP), allowing ports to track and benchmark their environmental performance annually.

Similarly, Darba et al. [76] proposes the Strategic Overview of Significant Environmental Aspects (SOSEA) methodology that helps port managers identify significant environmental aspects in order to reinforce the awareness about them and prioritize work in environmental management. Other conceptual and policy works emphasize the role of port management tools in developing environmental strategies that enhance the green image of ports [77], as well as of port energy management strategies to attain substantial efficiency gains, increase competitiveness, and alleviate the importance of energy conservation [78].

Additionally, port environmental sustainability has been approached through other methodological techniques. Chen and Pak [79] utilized Delphi to identify, after three rounds of iterations, a set of 21 applicable and practical green performance evaluation

indices in six dimensions (i.e., liquid pollution management, air pollution management, noise control, low-carbon regulations and energy savings, marine biology preservation, and organization and management). Respectively, in response to the lack of a comprehensive model for green port performance development evaluation, Wan et al. [80] applied the idea of the Drivers, Pressures, States, Impacts, and Responses (DPSIR) framework in the field of green ports, to develop a set of 16 suitable indices as a system for the (comparative) quantitative evaluation of green port development, while Chiu et al. [81] formulated a Fuzzy-Analytical Hierarchy Process (F-AHP) algorithm, which includes five dimensions and 13 factors to assess green port performance. Finally, Park and Yeo [82] utilized a fuzzy set approach along with factor analysis techniques to evaluate, based on 15 criteria, the greenness of major ports in Korea.

4.4. Social Impacts

An important, and as it appears from our review, under-researched area involves the assessment of the impacts and externalities ports exert on society. On the one hand, ports can affect positive well-being and quality of life in local communities, by contributing to the creation of direct and indirect employment, which, in turn, boosts the income of local communities and provides education and training opportunities for employees [81]. On the other hand, operational activities of ports, as well as port expansion projects, have also been the underlying factor of negative (mostly environmental) externalities, degrading welfare while increasing social costs borne by local communities and exacerbating conflicting interests between ports and their surrounding cities [83–85]. In any case, social impacts of ports are interlinked either to economic or environmental factors, or both.

4.5. Socio-Environmental

In the combined socio-environmental context, Lee et al. [86] highlighted the gap in the literature in assessing environmental efficiency of port cities, ranked the environmental efficiency of ports cities, and calculated the social cost for treating CO₂ emissions, as well as the opportunity cost for dealing with pollutant emissions. In turn, Maragkogianni and Papaefthimiou [37] employ an activity-based approach to create an inventory of exhausted emissions from cruise ships in the five busiest cruise ports in Greece, in order to estimate average aggregate external cost and anticipated health impacts of ship emissions. In a similar exercise, Chatzinikolaou et al. [87] employed an impact pathway approach to assess external costs in human health from ship air pollution in port areas, which according to their results, are not negligible. As ports become more socially oriented and acknowledging that port development and the derived negative externalities influence the quality of life of residents, Beskovnik and Bajec [88] proposed a six-pillar environmental model, which can be utilized for prioritizing environmental measures; these, in turn, promote a socially sustainable approach for port development. Antao et al. [89] adopted the utilization of indicators on the topics of Occupational Health, Safety, Security (OHSS), and Environment, to promote port performance measurement in order to assess and track the trends of socio-environmental issues over time.

4.6. Triple Bottom Line Approach: Economic–Social–Environmental

The triple bottom line approach of multidisciplinary studies, as opposed to solely economic, social, or environmental ones, attempts to capture the effects of ports and maritime trade combining additional factors, namely societal as well as environmental, in tandem. The development of environmental awareness by port cities, their hinterland, port users, and port authorities, the evolution and adoption of management systems, standards, and maritime regulation, among others, have led to a gradual realization of the need for a symbiotic relationship between the economy and the environment. Contemporary concepts, such as the Blue Economy or Green Ports, as well as measures and initiatives by

ports pertaining to corporate social responsibility, have been developed through an iterative and feedback process by policy makers, ports, and their stakeholders.

A common attribute shared by several economic and multidisciplinary studies is that as the economic impacts (mostly positive) spill over to the hinterland, neighbouring regions, countries, and even other countries connected with maritime trade routes, the same, albeit through different mechanisms, happens with environmental externalities. Identifying, assessing, measuring, and ultimately managing and mitigating these externalities has driven the development of a rich literature. This is evident from our multidisciplinary literature sample, comprising 17 research papers, spanning from 2003 to 2020, out of which 15 are quantitative studies, 1 is a qualitative study and 1 a conceptual paper [31], which is the most influential (412 citations). On average, our sample has 52 citations and 7.2 citations per paper annually, approximately 10% higher than our economic/social paper sample. This is counter-intuitive, since one would reasonably expect a wider gap, due to the fact that the inclusion of the environmental pillar has the potential to be of interest to a larger audience. This can be attributed to the average publication year in our sample being two more years compared to economic/social papers (2016 vs. 2014), indicating also more recent momentum in relevant research.

Economic/environmental and economic/social/environmental papers are nearly equally represented in our sample. Noting that one paper may include more than one research focus, the trend we observe is that, as opposed to economic and economic/social papers, more than one-third (36%) of multidisciplinary papers revolve around the concept of sustainability. A distinct portion of the papers (15%), such as Berechman and Tseng [33], Ballini and Bozzo [90], and Tichavska and Tovar, B. [91], specialize in identifying, measuring, and/or valuating environmental externalities. We also observe that: (a) the research area of sustainability/environmental raking of ports/port cities is concentrated mostly after 2016 (for example, see [92–94]), and (b) research for multidisciplinary composite indicators is even more concentrated between 2017 and 2021 (for example, see [95–97]).

We also report that compared with the economic and economic/social papers, this sample has broader as well as more diverse future research goals, with several papers [57,97–99] proposing more than two distinct future streams of work. Further research items ((a) case studies and (b) further elaboration on the scope and methodologies) are the most frequent, equally represented by approximately a third each of our sample. The third most frequent direction of future research is ‘none’, while the category of port governance and policy is double in comparison with the economic papers sample.

In our sample of multidisciplinary papers, a new category for future research emerges, namely corporate social responsibility (see [21,97,99]). Important future research aspects that appear to be under-represented are logistics, road and rail transportation, the role of ports as part of the supply chain, as well as tools and methods for the evaluation of port-related investments. Finally, we find there is considerable room for exploring new ‘basic’ research concepts in individual/specific areas, which, in turn, can be utilized in multidisciplinary port applications, as well as a common measure or a dashboard on a sectoral level.

5. Conclusions and Further Research

In this work, we focused on reviewing and classifying the state-of-the-art literature on port impacts and externalities, attempting also to capture streams of literature and fields of research as well as the economic, social, environmental, and multidimensional metrics and indicators pertaining to the port industry. Our ultimate goal included the identification of research trends and gaps within a final sample of literature, which we constrained according to set criteria.

Trends and gaps included in our review are not limited to general research fields, but also include sub-fields, including multidisciplinary indicators, an essential component for

port evaluation, as well as strategic, operational planning, and benchmarking tools. Despite the fact that port externalities can be considered a relatively narrow field of research, the diversity of the research items is considerable, spanning from general literature streams of port governance and policy, port economics and management, port operations, and efficiency, to very specialized literature, such as, for example, valuation of specific environmental factors, and new port technologies and services, including cold ironing. This diversity, which is also acknowledged in [8,12,21,22,95], appears to stem from the fact that research on port externalities attracts a substantial number of distinct authors, many of whom address the subject under study from diverse perspectives and viewpoints. Accordingly, considering the significant number of distinct academic journals in our sample, in conjunction to its chronological distribution, it could be argued that the former is more keen on publishing relevant research in the field of port externalities and impacts over the course of years, stimulating, thus, further diversity.

Our final sample of 71 papers—taking into account our inclusion criteria, as well as the review methodology—can be considered as a medium-sized one. Nevertheless, judging from the difference in the average citations per year of the entire sample (7.8) and the subset of papers having more than 100 citations (14.8), it is evident that the impact of the latter is considerable, addressing research questions not limited to one field. Furthermore, we find that the number of conceptual/theoretical papers is small, but on average, more influential than case studies or very specialized papers. General trends we observe with respect to multidisciplinary papers is that the research areas of sustainability/environmental ranking of ports/port cities and multidisciplinary composite indicators are more concentrated in recent years, rather than 20 years ago. In addition, the basis of evaluation is expanding from single ports or port cities to entire regions [80,100], and tends to incorporate additional dimensions and links to the port sector, such as Munim and Schramm [48] with logistics and trade, and Park and Seo [52], where maritime, land, and air transportation are covered.

Another common trend is multidisciplinary studies, with the inclusion of environmental and social aspects [101] to the existing dominant substrate of studies covering economic and operational/productivity aspects. In this respect, our results are in line with [21], which suggests that port literature increasingly adopts a more holistic approach on port sustainability, addressing concurrently the economic, environmental, and social impacts of port externalities. However, along with [12,74], our findings suggest that still the most common aspect of sustainability researched revolves around the issue of environmental port externalities. Even though research on environmental indicators is particularly active, our results indicate that there is still room for port literature to develop a common language with environmental literature. In addition, we also observe that (a) there is a higher level of indicator standardization in economic and financial literature, notwithstanding their diversification with respect to methodologies employed, and (b) social aspects of port development and operation, as well as social indicators, have been less comprehensively covered and are less standardized.

It is important to note that none of the papers in our final sample address solely societal impacts of ports. While some relevant social indicators were established (well-being and safety of port employees), to our best knowledge, the well-being of the surrounding communities has not been assessed in detail. Since these communities are the primal recipients of negative externalities, more attention should be paid on identifying and addressing their interests and needs. Enhancing the participation of local communities and stakeholders and measuring the impact of ports and their quality of life through representative social indicators may also facilitate the setting of collaborative sustainability goals, both by the community and the port. As such, in accordance with [21,22], exploring whether ports that encompass the societal interests of surrounding communities also enhance their sustainability performance is also an interesting topic for further research, as well as relevant research from the viewpoint of corporate social responsibility [99]. Accordingly, the application of the ESG criteria, which has been gaining more attention in

recent years, in the context of the port industry, could also be an additional future research path, yielding interesting results on the extent to which ports (i.e., port managing bodies, terminals, port complexes, etc.) operate to serve wider societal goals rather than just solely pursuing the maximization of profits as the shareholder theory suggests. Finally, in addition to the above, while there are many case studies that evaluate the sustainability performance of ports, a common framework on port sustainability enablers [14] or a common measure or a dashboard on a sectoral level has not been yet proposed or established.

Furthermore, in contrast to previous studies, we find that case studies pertaining to individual ports tend not to focus on adverse implications or, in general, being negative or critical to port development, indicating a potential publication bias. Examples of critical works are Morrissey et al. [102] and Busquet et al. [103], neither of which met our criteria for inclusion in our final review sample, but we view them as important for our argument. Apart from the evolving multidisciplinary approaches, for which our view is that considerable room for exploring new concepts exists, there is also scope for more ‘basic’ research in individual areas, for the evaluation of, among others, new technologies, ship designs, new fuels, as well as new services that affect port planning and operation, and consequently, its hinterland. In turn, the results of this specialized research will be utilized in multidisciplinary and comparative [99] port applications.

Supplementary to previous studies, our analysis indicates that the coverage of evaluation of port investments in a multidisciplinary fashion, incorporating aspects of port policy and management, is rather limited. Since a multitude of tools and methods to evaluate an existing port, or at least a finalized concept design, exist, in line with [12,21,95], we argue that a comprehensive multidisciplinary approach, probably also involving composite sustainability indicators, is warranted, with its major focus being ex-ante evaluation. This kind of evaluation, in our view, could also incorporate port governance and policy aspects, as well as port-management-related decisions, such as, among others, implementation of environmental management systems and corporate social responsibility measures, and any other factor capable of affecting not only the port itself, but also its hinterland. With respect to the latter, a global maritime, rail and road transportation, and logistics perception, is also warranted, in line with [19], since there is little value in viewing port development in isolation.

Finally, the nature of the current systematic literature review was to identify, record, and meta-analyse trends and gaps within the existing literature on the issue of ports’ externalities and impacts, and in this sense, it does not construct a novel theoretical or applied framework on how to treat port externalities in an inclusive and holistic manner. In addition to the above, another limitation stems from the fact that there is a potential overlap with respect to theoretical/conceptual contributions as well as case studies between our sample and papers assessing aspects of port investments, which we only covered partially. Since we intend to have the capability to expand our future work in the direction of port investments, assessing the relevant bibliography is an opportunity for future work.

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