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A bibliometric analysis of sustainable development goals in the maritime industry and port sector

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ABSTRACT

The maritime industry, a cornerstone of global economic growth and development, is inextricably linked to the function of ports, serving as vital infrastructure for economic expansion. The present article undertakes a comprehensive review of extant literature, identifying sustainability trends that align with the Sustainable Development Goals (SDGs) within both the maritime industry and the port sector. A bibliometric analysis was conducted utilising the capabilities of IRaMuTeQ and VOSviewer software. Upon examination of the research outputs, associations with terms such as “port city model”, “circular economy”, “blue economy”, and “energy efficiency” emerged as dominant research directions. A qualitative examination was undertaken based on classifications by keywords, authors, content, and origin of publications. This analysis revealed a marked prominence of the European context within these studies, indicating an academic emphasis on the numerous ports in Europe. Furthermore, it was observed that a significant proportion of the research is affiliated with esteemed publishers such as the Multidisciplinary Digital Publishing Institute, Taylor & Francis, and Elsevier. Notably, areas demonstrating significant research potential revolve around themes of sustainability, management, and maritime policies. Despite a noticeable increase in publications, a clear academic gap remains. This is particularly evident when considering the complexities of aligning port-specific operations with the ambitious 2030 Agenda. By addressing this shortfall, this study contributes to the academic discourse on SDGs within the maritime and port sectors. Moreover, it advocates for strategic policy shifts in line with the SDGs. Ample evidence underscores the pressing need for increased interdisciplinary cooperation in this field. A salient observation from this study underscores the necessity for enhanced interdisciplinary collaboration.

1. Introduction

The maritime industry plays an essential role in the expansion and development of the world economy. With the increased demand for containerized cargo shipping, world maritime trade rebounded in 2021 across all developing regions, with shipments growing by around 3.2% to reach 11 billion tonnes. This represents a marked improvement, a swing of 7% points from the lamentable 3.8% decline witnessed in the year prior, 2020 (UN, 2022).

Ports represent a vital component of the maritime industry, serving as crucial infrastructure for economic expansion. As conduits for international trade, they facilitate the operations of cargo loading and unloading and offer value-added services (Calcerano and Hilsdorf, 2021;

Hossain et al., 2021). The role of the maritime industry and the port sector as drivers of international trade highlight the importance of port sustainability. Ports serve as nexus points within global supply chains, engendering externalities that extend to the oceans and seas, to the detriment of marine ecosystems and local communities (Oh et al., 2018).

Sustainable economic development is one of the critical agendas for port authorities (Lim et al., 2019). Due to the scope and nature of the activities carried out by the port sector, environmental externalities are generated by maritime activities, port operations, and land transport. As these actions intensify, so too will the quantity and variety of ecological, economic, and social impacts. Examples of these impacts, caused by the port sector and maritime industry, include noise pollution, atmospheric pollution contributing to the greenhouse effect and climate change,

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water pollution, damage to marine biodiversity, the discharge of sewage by large vessels, and oil spills (Walker et al., 2019; Kandasamy et al., 2021; Puig et al., 2022; Soares et al., 2022).

The port sustainability, underscored by environmental and social metrics, mitigates harmful impacts on marine biodiversity, atmospheric conditions, and the quality of life for employees and adjacent communities. It is paramount that the economic dimension aligns with port performance whilst concurrently contributing to environmental and social sustainability (Alamouh et al., 2021a). This balanced integration of economic, environmental, and social perspectives is vital for the holistic success and resilience of port operations.

It is imperative for port cities to adopt innovative and integrated approaches that align with the principles of Circular Economy to effectively address sustainability challenges. These urban locales, characterized by diverse forms of integration, serve as pivotal arenas for managing the transition to circular systems. Such a transition has the potential to catalyze territorial productivity, foster economic development, and reinforce social cohesion. Within this framework, it is incumbent upon port authorities and municipal bodies to undertake initiatives for circular transformation. Moreover, these entities must establish mechanisms for ongoing dialogue and interaction among a multitude of stakeholders. (Cerreta et al., 2020b).

Informed by this underlying impetus, discussions surrounding sustainability have permeated various nations and sectors since the 1980 s. The paradigm of "sustainable development" gained significant traction in 1987 with the publication of the Brundtland Report, formally known as "Our Common Future", produced by the World Commission on Environment and Development. This pioneering document emphasised the imperative of adopting a synchronised and holistic approach towards economic, social, and environmental progress (UN, 2023).

Henceforth, galvanised by the principles of sustainable development, the maritime and port industry acknowledged that its ramifications transcend mere direct operations. This sector grasped its obligations to the environment, local communities, and the broader global economy. Such an acknowledgment ran in tandem with international endeavours, including the Millennium Declaration and the Development Goals established in 2000, which engendered dialogues regarding the participation of diverse stakeholders in realising global objectives.

In 2015, world leaders augmented these efforts by adopting the 2030 Agenda for Sustainable Development, a comprehensive global action plan encompassing 17 Sustainable Development Goals (SDGs). These SDGs address pressing challenges such as climate change, social inequality, and environmental degradation. Achieving these ambitious yet essential goals require unified efforts from governments, businesses, and civil society organisations. The maritime industry plays a crucial role in this endeavour. The marine and port industry, when guided by sustainable development principles, can significantly contribute to the realisation of these global goals. Collaboration is critical to building a just and sustainable society. The maritime industry's growth is vital in implementing the 2030 Agenda and the corresponding SDGs (Benamara et al., 2019; Khaled et al., 2021).

Although the main correlation of the maritime industry with the SDGs found in the scientific literature is with SDG 14, related to sustainability applied to marine spaces, the contribution of the port sector, as discussed in Caliskan (2022) extends to encompass SDGs 8, 9, 11, 12, 13 and 17. In addition, it is also important to highlight that sustainability actions related to the port industry are related to each other, that is, some SDGs are interconnected.

Consequently, endeavours aimed at diminishing the detrimental impacts associated with maritime ports, particularly in the environmental and socio-cultural spheres, are encompassed by the term "port sustainability". The importance of this concept has grown exponentially over recent decades, due to the breadth of port-related activities and the increasing demand from various stakeholders for the adoption of more sustainable operational practices.

Port sustainability can make a significant contribution to the

Sustainable Development Goals (SDGs), an international framework focused on abolishing poverty, addressing disparities both within and between nations, promoting societal inclusion, and preserving the planet whilst ensuring economic viability (Alamouh et al., 2021a).

From a social perspective, the maritime industry must invest in gender equality, training women, improving workplaces, and creating positive jobs for the female public. The health and safety of employees are priority issues for the sector, as well as social programs that aim to compensate for the damage caused to communities. From an environmental perspective, investments should be directed towards reducing pollution related to maritime transport in the oceans, ports, and coastal regions, underscoring the indispensability of promoting financing, research, and development in clean energies (Cunha et al., 2023; IMO, 2017).

Likewise, the adoption of digitization and the use of advanced technologies aimed at improving the efficiency of the emissions assessment process in the port sector reduces failures and increases the reliability of the data collected, facilitating the standardization of the assessment activity, and encouraging the use of clean energy sources (Del Giudice et al., 2022).

The United Nations (UN), through the SDGs, underscores the fundamental role of partnerships and global cooperation of various stakeholders for the fulfilment of the 2030 Agenda. Di Vaio et al., 2023a emphasise that the establishment of multisectoral partnerships serves as a foundation for improving sustainable performance, facilitating the mitigation of externalities, designing innovative sustainable products and the application of new technologies.

According to Wang et al. (2020), despite the significant relevance of the maritime industry in contributing to the SDGs, there is a dearth of studies related to this topic, highlighting a research gap that comprehensively assesses all SDGs and their collective implications for the sustainable development of the sector.

The integration of the maritime and port sectors with the Sustainable Development Goals (SDGs) represents an evolving domain of knowledge. Although specific studies offer valuable insights, there is a noticeable lack of a comprehensive synthesis that cohesively combines these insights into a unified research narrative.

In this context, this paper examines existing literature and identifies sustainability trends tied to the Sustainable Development Goals (SDGs) within the maritime industry and port sector. Acknowledging the research lacuna, our study employs bibliometric analyses—a robust methodology for charting academic trajectories. Utilising advanced analytical tools, namely VOSviewer and IRaMuTeQ, the study delineates interrelationships among key terms, underscoring dominant research themes. Furthermore, the research sheds light on pertinent case studies centred around prominent global ports.

2. Literature Review

The literature addressing the maritime industry and port sector to sustainability, particularly in the context of integrating the United Nations Sustainable Development Goals (SDGs), exhibits a discernible paucity, especially concerning the exploration of linkages between the SDGs and the maritime and port sectors. Concurrently, several scholarly inquiries have concentrated on prominent global ports, as evidenced by the works of Michalska-Szajer et al. (2021), Taneja et al. (2021), Fedorenko and Khmeleva (2021), and Caliskan (2022). Notably, the extent of research explicitly focusing on ports in emerging economies within SDG-related studies remains conspicuously limited. Table 3 details sixteen studies from the sample of papers thirty-two that were applied to ports, mainly to European ports.

In the research conducted by Michalska-Szajer et al. (2021), it was suggested that the governance bodies of the preeminent Polish ports exhibit social responsibility, proactively instituting measures across the social, environmental, and economic dimensions. Yet, they clarified that the magnitude and breadth of these endeavours remain subdued when

Table 3
Research with case studies.

Study	Objective	Ports	Country	Continent
Al Amien et al. (2020)	To assess the impact of the Port of Mafa's development on five UN SDGs and its link to regional growth in Indonesia.	Mafa	Indonesia	Asian
Argyriou et al. (2022)	To provide a methodology for policymakers to develop their future strategies for optimizing sustainable multiobjective.	Souda	Greece	Europe
Beleya et al. (2020)	Identify the main challenges to achieve the sustainable development goals (SDGs), with a focus on the Klang port.	Klang	Malaysia	Asian
Caliskan (2022)	To develop a comprehensive framework of port related sustainability.	Algeciras, Aliaga, Ambarli, Amsterdam, Antwerp, Barcelona, Bergen, Bilbao, Botas, Bremerhaven, Constanta, Dunkerque, Felixstowe, Gdansk, Genova, Gioia Tauro, Gothenburg, Hamburg, Immingham, Kocaeli/Izmit, Iskenderun, La Havre, La Spezia, Las Palmas, Liverpool, London, Marseille, Medway, Mersin, Milford Haven, Piraeus, Riga, Rotterdam, Sines, Southampton, Tallinn, Taranto, Tees & Hartlepool, Trieste, Valencia, Wilhelmshaven and Zeebrugge	Spain, Turkey, Netherlands, Belgium, Norway, Germany, Romania, France, United Kingdom, Poland, Italy, Sweden, Greece, Latvia, Portugal, Estonia	Europe
Cavalli et al. (2021)	To evaluate the impact of 5 G technologies on aligning port operations with UN SDGs, and to use this understanding to guide the development of future port management models and policies.	Livorno	Italy	Europe
Cerreta et al., 2020a	To devise a flexible decision-making approach for Naples' commercial system that prioritizes sustainable city-port relations and implements Circular Economy principles.	Naples	Italy	Europe
Cerreta et al., 2020b	To identify sustainable design strategies for the port-city relationship, in the city of Naples, from a set of indicators, within a multidimensional and multi-scale decision support system.	Naples	Italy	Europe
D'Amico et al. (2021)	To conduct a literature review on prevalent themes in smart and sustainable logistics in port cities and develop a framework that integrates key favorable factors.	Rotterdam, Amsterdam, Los Angeles, Antwerp, Montreal, Hamburg, Hanian, Valencia, Stockholm, and Singapore	Netherlands, United States of America, Belgium, Canada, Germany, China, Spain, Sweden, and Singapore	Europe, North America, Asian
Lima and Souza (2022)	Identify and evaluate the extent to which the climate change topic is addressed by the port planning, coastal management and climate adaptation policies of Brazil.	São Francisco do Sul, Itapoá, Itajaí, Navegantes and Imbituba	Brazil	South America
Fedorenko and Khmeleva (2021)	To evaluate the challenges and benefits of applying sustainable development principles in free ports, using a comparative analysis of the Vladivostok free port's activities and the sustainable practices of the port of Antwerp.	Vladivostok and Antwerp	Russia and Belgium	Europe
Idris (2022)	To review maritime sector initiatives in select Southeast Asian countries aimed at meeting the 2030 Agenda on Sustainable Development, focusing on SDG17.	Singapore, Klang, Tanjung Pelepas	Singapore and Malaysia	Asian
Jansen et al. (2018)	To explore and analyze conditions for inclusive port development, presenting initial findings and highlighting areas for future research.	Tanjung Carat	Indonesia	Asian
Katuwawala and Bandara (2022)	To identify the reasons for the stagnant behavior of seaports contributing to Sustainable Development Goals.	Colombo and Hambantota International	Sri Lanka	Asian
Michalska-Szajer et al. (2021)	To assess the social responsibility of the seaports in Gdansk, Gdynia, Szczecin, and Swinoujscie, identifying any gaps, and offering insights for their management entities.	Gdansk, Gdynia, Szczecin, Swinoujscie, Hamburg and Antwerp	Polish, Germany, Belgium	Europe
Nitsenko et al. (2017)	To propose a monitoring tool for commercial maritime ports' business models to evaluate performance and align with sustainable development goals and indicators.	Oktyabrsk	Ukraine	Europe
Taneja et al. (2021)	To evaluate the sustainability of port infrastructure, showcasing a case study on a quay wall in the Port of Rotterdam.	Rotterdam	Netherlands	Europe

compared with practices observed at the ports of Antwerp and Hamburg. The disparities were most pronounced within the social and environmental facets.

The study by Taneja et al. (2021) highlights that enhancing the sustainability performance of port infrastructure necessitates identifying

all pertinent sustainability aspects, defining appropriate performance measures, employing tools for quantification, and proposing intervention strategies. The authors present a model for the Port of Rotterdam, wherein they assess four sustainability themes.

In the paper by Fedorenko and Khmeleva (2021), the authors

undertake a comparative analysis of the ports of Vladivostok and Antwerp, probing into the challenges and opportunities tied to the implementation of sustainable development principles. Their findings highlight that a narrow focus on economic and social objectives may fall short in ensuring robust management of coastal zones. Antwerp emerges as a benchmark in uniting economic competitiveness with sustainable development, exemplified by its comprehensive sustainable development policy anchored in SDGs 3, 8, 9, 11, and 13.

The research by Caliskan (2022) offers significant contributions to the application of the SDGs in the port sector. The research connects port sustainability practices with the SDGs. The findings emphasise the potential of the port industry to substantially contribute to SDGs 8, 9, 11, 12, 13 and 17.

The increasing focus in academic discourse, as evidenced by the studies of Moratis and Melissen (2018), Di Vaio et al. (2020), Del Giudice et al. (2022), Cavalli et al. (2021), MacNeil et al. (2022), Katuwala and Bandara (2022), and Di Vaio et al. (2022), underscores the centrality of the Sustainable Development Goals (SDGs) within the maritime and port sectors.

Moratis and Melissen (2018) initiated the discourse by observing a selective emphasis on SDGs by organisations, specifically those which dovetail with their immediate business objectives. Such a short-sighted view, they argue, tends to inadvertently skew priorities towards short-term profitability at the potential expense of broader societal well-being. They advocate for a comprehensive, rather than a selective, approach to SDGs.

Building on this foundation, the maritime industry, inherently dynamic in its nature, finds itself at a crossroads of evolving sustainability paradigms. The 2030 Agenda, embodying the SDGs, offers this industry a compass to navigate the tumultuous waters of corporate sustainability. Di Vaio et al. (2020) further refined this narrative, highlighting the importance of discerning between genuine sustainable initiatives and mere compliance with legislative requirements.

Del Giudice et al. (2022) highlighted the paramount significance of digitalisation and emergent technologies in integrating sustainability into business practices, with a specific emphasis on the maritime sector. The prominence of these technologies is amplified by their capacity to confront and potentially overcome existing challenges, notably those associated with energy consumption and emissions.

Cavalli et al. (2021) probed into the granular implications of SDGs by elucidating the transformative capabilities of 5 G technology in the Port of Livorno. Such technological advancements, they posit, find resonance with multiple SDGs, both directly and indirectly, exemplifying the interdependence of technological innovations and sustainable outcomes.

On a similar note, MacNeil et al. (2022) mapped out the SDGs—specifically 3, 6, 9, 11, 12, 14, 15, and 17—that are directly pertinent to the Canadian port sector, juxtaposing them with the performance indicators of the Green Marine Environmental Program.

Di Vaio et al. (2022) study identifies best practices utilised aboard cruise ships to achieve sustainability objectives in digital waste management. This research presents an essential guide for industry professionals, emphasising the criticality of involving crew and passengers in the digital waste management process. Recent systematic review studies have highlighted the Sustainable Development Goals (SDGs) within the maritime and port sectors. The research by Diniz et al. (2023) provides a detailed examination of the SDGs presented in the literature. Di Vaio et al., 2023b study delves into green technologies in decarbonization management practices and explores gender equality. Another investigation by Di Vaio et al., 2023a elucidates the role and potential of blockchain technology in promoting gender equity.

3. Method

In this study, a bibliometric analysis was utilised as the primary quantitative method, which was further complemented by qualitative

content analysis. Two pivotal software applications, VOSviewer and IRaMuTeQ, played instrumental roles in deriving the outcomes of this process.

The VOSviewer software was specifically used to produce maps and facilitate the bibliometric analysis. Through this application, we were able to pinpoint prevalent trends, identify gaps in literature, discern prospective research areas, highlight leading countries, sources, authors, and elucidate the relationships among keywords (Mas-Tur et al., 2021).

The VOSviewer software is an open-source bibliometric network design and development tool. A mapping visualisation of the bibliographic data was created to acquire more comprehensive and profound insights into the bibliometric findings (Di Vaio et al., 2023a).

Simultaneously, IRaMuTeQ, an open-source program harnessing the analytical prowess of the R programming language, was utilized. This software falls under the domain of IT tools used in data mining, adept at extracting data from textual materials. It structures the extracted data by identifying keywords, phrases, and sentences, subsequently encoding them into numerical variables. This data then undergoes statistical processing to uncover, and often visualize, the inherent relationships between them. In this study, the role of IRaMuTeQ was pivotal in validating the interpretations derived from the literature review (Frankowska et al., 2022).

Data were obtained from the Web of Science and Scopus platforms, using the keywords “Sustainable Development Goals” and “ports” or “SDG” and “ports” in the topic field, in the period from 2017 to 2022. Chosen because the 2030 Agenda, which encompasses the Sustainable Development Goals (SDGs), was approved on 25 September 2015. We chose to use studies published between 2017 and 2022, covering a 5-year cycle. The year 2023 was deliberately excluded as it is still in progress.

In our exploration of the Web of Science database, a filter was applied to select articles and review papers, yielding a total of 55 papers. Simultaneously, the Scopus database was searched using identical criteria within the title / abstract / keywords field, and for the same period, types, and language of documents as applied in the Web of Science database. This search generated 62 papers, amassing a total of 117 documents.

Then, we transferred these documents to the Endnote system, to perform the first content analysis and select only the articles that dealt with the SDG and ports in within their content. With this objective, we analysed each article individually, verifying if the theme was present in the studies. We observed that in some studies, the term “port” was used as the name of cities, which did not correspond to the intended meaning for this review. Furthermore, in some studies in the sample, the word “SDG” was only present in the abstract or conclusions and, in most cases, it was not related to the ports.

We eliminated duplicate articles and those not pertinent to the study topic. Following this analysis, 85 studies were discarded, leaving a final sample of 32 papers. These were further analysed and categorised based on the study context. The objectives of all articles were extracted, along with specific cataloguing criteria related to the type of SDG mentioned in the studies. This information was consolidated into a single textual corpus for analysis in IRaMuTeQ. From the constructed corpus, we could discern the conceptual relationships between the terms “Sustainable Development Goals”, “SDG”, and “port” within the sample articles, enhancing our understanding of the discussed topics.

The bibliometric analysis was subsequently conducted on these 32 papers. Their findings were evaluated and deliberated upon, drawing from the results generated by the VOSviewer software and analyses executed in IRaMuTeQ. The VOSviewer facilitated the creation of Figs. 3 to 9 presented in this study’s results section.

4. Results

To determine the maritime industry and port sector’s contributions

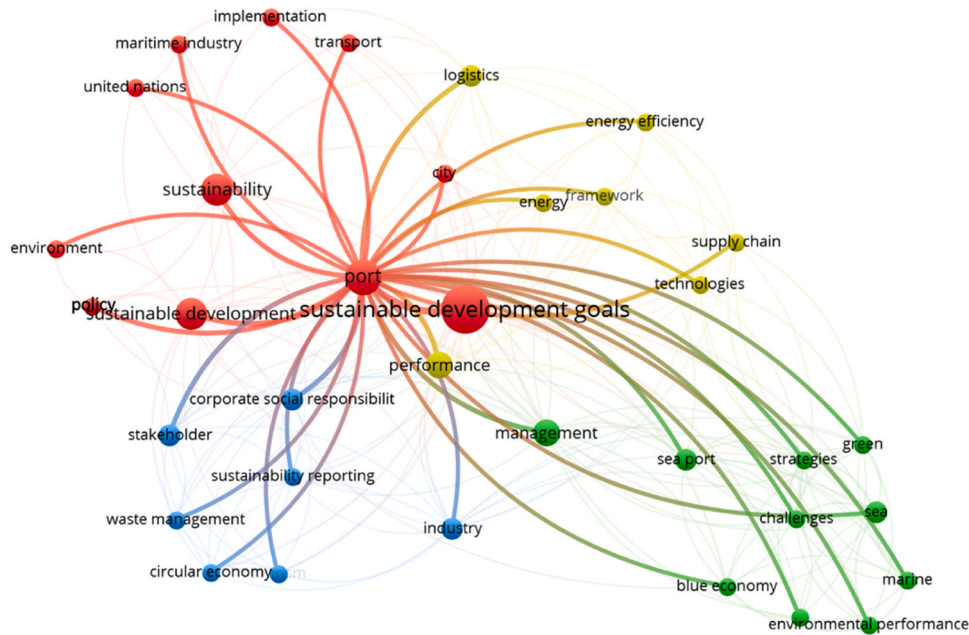


Fig. 5. Relationships of the keyword 'port' with other keywords that appear twice.

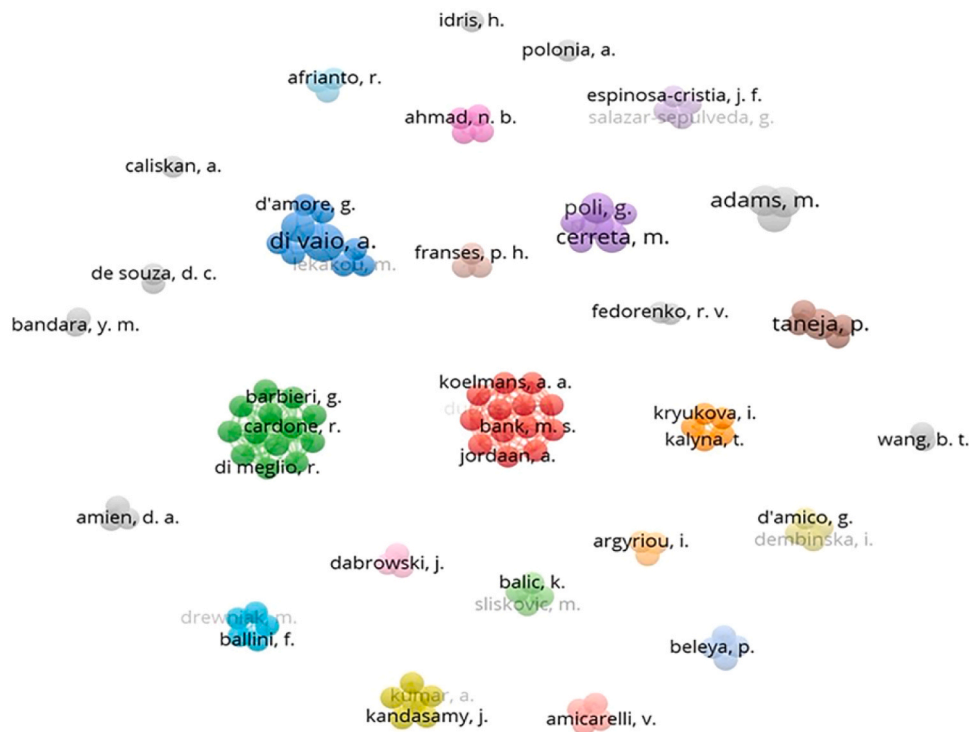


Fig. 6. Collaboration between authors.

content analysis, verifying that the selected studies agree with the proposed theme. The total amount of keywords used in the papers was 245, but only 53 appeared at least twice (Fig. 3), the others being hidden because they are not repeated. There is emphasis on the term “sustainable development goals” with the highest number of appearances (17) as a keyword used, in addition to the term’s “port” (9), “sustainability” and “sustainable development” with 7 appearances each and “performance” and “management” with 5 and “port sustainability” with 4.

In bibliometric and keyword network analyses, the interrelations among clusters can act as signposts pointing to prevailing research

trajectories. By scrutinizing the interconnectedness and spatial closeness of these clusters, scholars can identify recurrently co-investigated themes or areas increasingly gaining traction in the academic discourse. Additionally, tracking the temporal progression of these clusters provides a lens to ascertain the evolving direction of a specific research domain. Consequently, cluster analysis emerges as an invaluable tool for both detecting and projecting nascent trends within a designated research context.

In this study, the terms “sustainable development goals” and “port” were scrutinized. Fig. 4 displays the relationships of the largest cluster

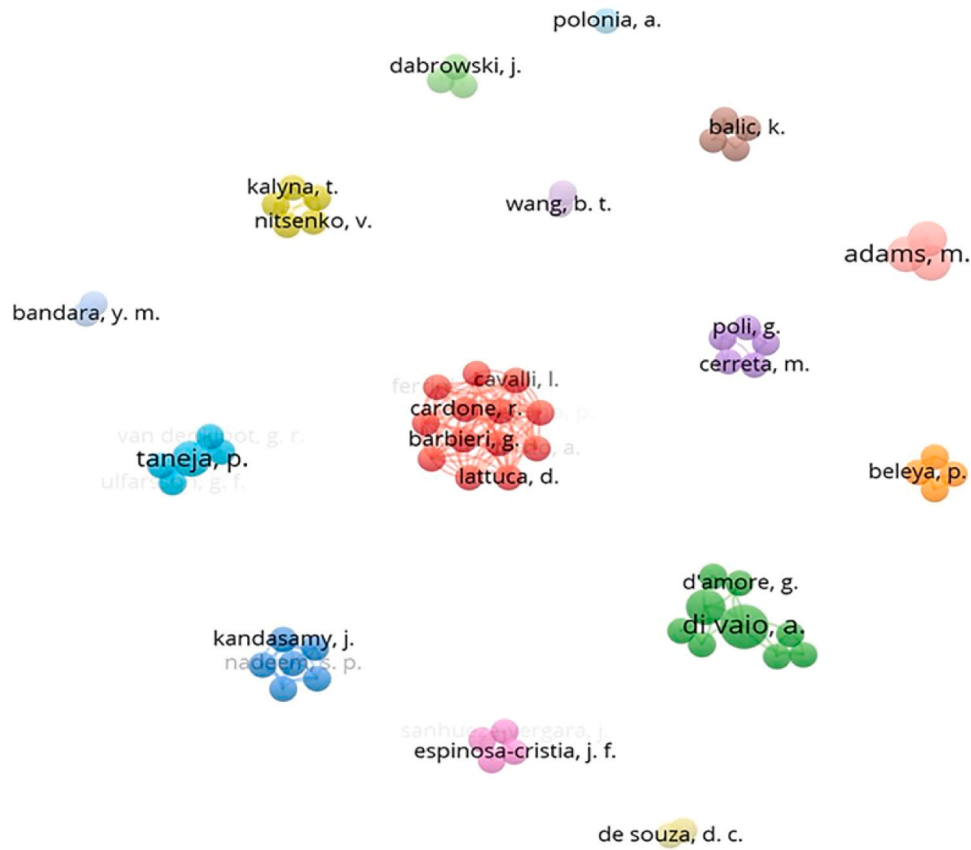


Fig. 7. Collaboration between authors who used the keyword "Sustainable Development Goals".

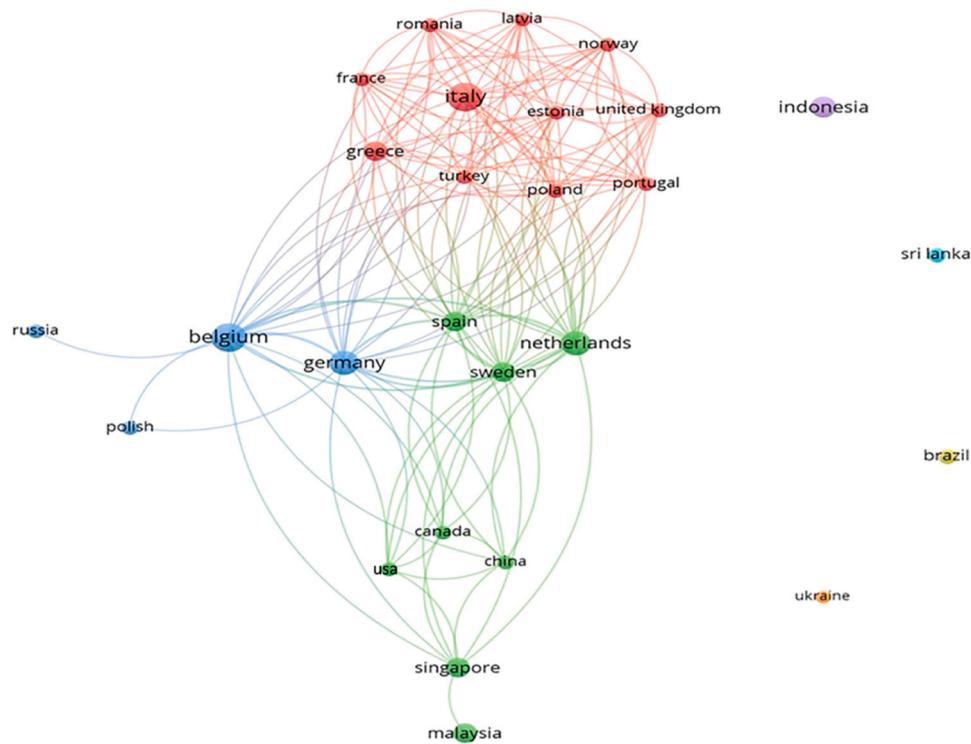


Fig. 8. Connections between countries.

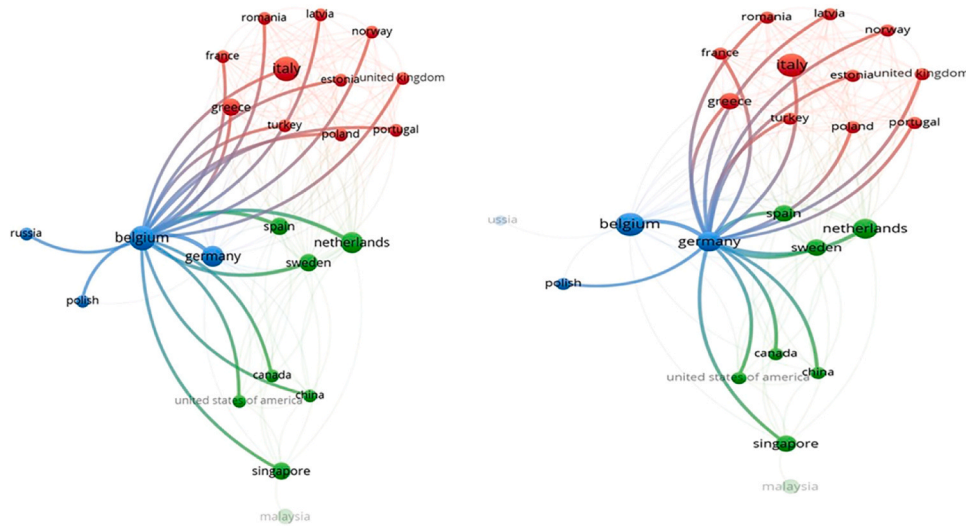


Fig. 9. Relations with Belgium(a) and Germany(b).

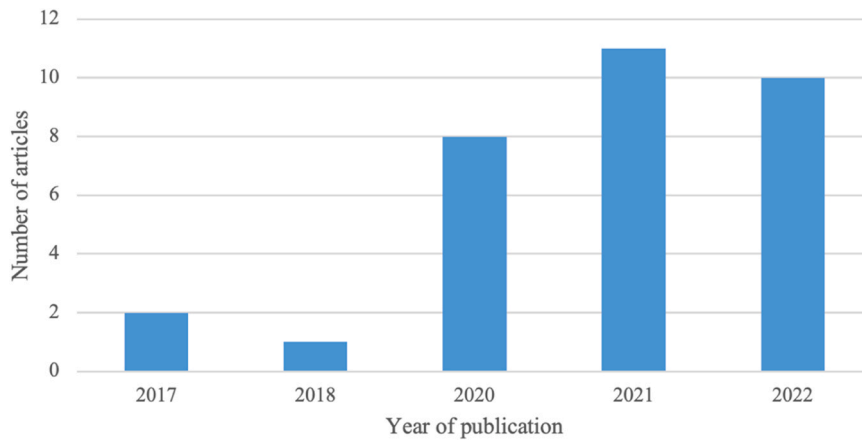


Fig. 1. Evolution of publications.

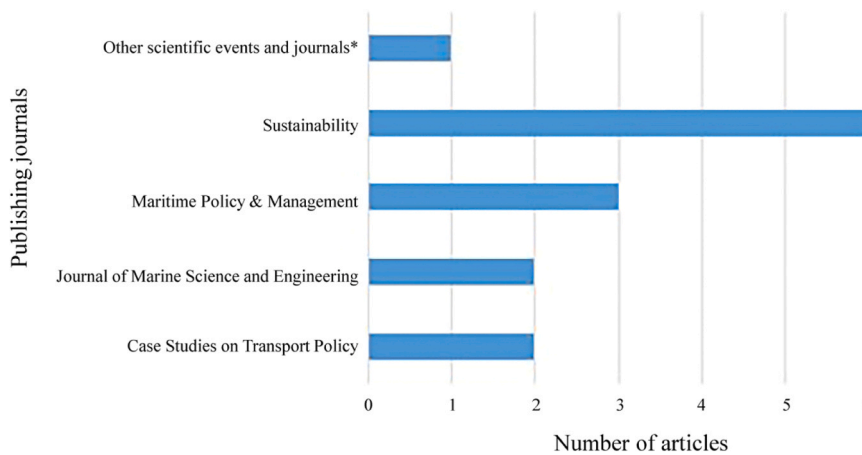


Fig. 2. Publications by journals. *Note: The other 19 journals and events that have only one publication each.

formed from the existing 245 keywords. This cluster contains 238 terms. The keyword “sustainable development goals” has the highest number of relationships with other words, such as “port management”, “city port model” and “circular economy”.

In evaluating the research outputs, the association with terms such as

“port city model”, “circular economy”, “blue economy”, and “energy efficiency” illuminates the predominant research trajectories. The confluence of economic growth and environmental sustainability emerges as a paramount challenge in aligning the maritime and port sectors with the SDGs. The recurring emphasis on concepts like “circular

Table 1
List of the 32 selected papers.

Author (s)	Year	Journal/events
Kitada et al.	2017	The 18th Annual General Assembly: IAMU 2017
Nitsenko et al.	2017	Journal of Security and Sustainability Issues
Jansen et al.	2018	Maritime Policy & Management
Ahmad et al.	2020	Journal of Critical Reviews
Al Amien et al.	2020	The 2nd Maritime Science and Advanced Technology: MSAT 2019
Beleya et al.	2020	Sciences in Cold and Arid Regions
Cerreta et al.	2020	Sustainability
Cerreta et al.	2020	20th International Conference on Computational Science and Its Applications (ICCSA)
Di Vaio et al.	2020	Maritime Policy & Management
Polónia	2020	International Journal of Maritime History
Wang and Wang	2020	International Conference on Sustainable Civil Engineering and Architecture, 2019
Balić et al.	2021	Pedagogika-Pedagogy
Bank et al.	2021	Environmental Science & Technology
Cavalli et al.	2021	Sustainability
D'Amico et al.	2021	Sustainable Cities and Society
Fedorenko and Khmeleva	2021	Journal of Marine Science and Engineering
Kandasamy et al.	2021	Sustainable Development
Knapp et al.	2021	Maritime Transport Research
MacNeil et al.	2021	Sustainability
Michalska-Szajer et al.	2021	Case Studies on Transport Policy
Taneja et al.	2021	Sustainability
Vega-Muñoz et al.	2021	Sustainability
Argyriou et al.	2022	Case Studies on Transport Policy
Caliskan	2022	Journal of Cleaner Production
Del Giudice et al.	2022	Maritime Policy & Management
Di Vaio et al.	2022	Ieee Transactions on Engineering Management
Eskafi et al.	2022	Journal of Marine Science and Engineering
Idris	2022	Akademika
Katuwawala and Bandara	2022	Maritime Business Review
Lima and Souza	2022	Regional Studies in Marine Science
MacNeil et al.	2022	Sustainability
Varese et al.	2022	Environments

Table 2
Main occurrences and relationships of keywords.

Keyword	Occurrences	Total link strength
Sustainable development goals	17	162
Port	9	90
Sustainable development	7	82
Sustainability	7	70
Performance	5	72
Management	5	64
Port sustainability	4	34
Sea	3	42
Sea port	3	42
Industry	3	40
Logistics	3	39
Corporate social responsibility	3	36
Emissions	3	35
Stakeholder	3	34
Blue economy	2	38
Energy efficiency	2	35
Challenges	2	33
Green	2	33
Strategies	2	33
Sustainability reporting	2	33

economy", "blue economy", and "energy efficiency" underscores the urgent necessity for substantial investments in clean technologies and sustainable operational practices, thereby challenging established business models. Furthermore, the effective integration of sustainable development strategies demands a holistic approach, extending beyond mere port operations to include associated supply chains and logistics,

thereby amplifying the scope and complexity of the endeavours required to realise the SDGs.

Upon examination of the keyword "port", one can discern notable associations with several terms, particularly: "sustainable development goals", "sustainable development", "performance", and "management" (Fig. 5). Specifically, the keyword 'port' interacts with 34 other terms, with 23 of them making a singular appearance as a keyword in the research.

Delving deeper into the literature, studies by Balić et al. (2021), Lima and Souza (2022), and Vega-Muñoz et al. (2021) not only incorporate both "sustainable development goals" and "ports" in their abstracts but also engage in discussions about the integration of sustainable practices and methodologies targeted at SDGs within the port sector.

The analysis of the total number of authors involved in the sampled studies reveals a pronounced internal collaboration bias. This bias manifests as a tendency for authors to primarily collaborate within the confines of a single article, rather than extending their collaborations across different articles, indicating a constrained scope of inter-authorial partnership. This insight was gleaned from data processed utilising the VOSviewer software.

Within the scope of the 32 scrutinised publications, contributions emerged from 115 individual authors. Di Vaio, A. stands out with a commendable three publications, whereas authors such as Adams, M.; Cerreta, M.; Hassan, R.; Macneil, J.L.; Poli, G.; Regalbutto, S.; Taneja, P.; and Walker, T. R. each have made their mark with two published articles. Notably, the rest of the authors have each participated in merely a single publication. This statistic prominently highlights that only a limited number of authors, nine to be precise, have engaged more than once in the discourse surrounding SDGs in port-related contexts (see Fig. 6).

The dominance of authors contributing just once to this research area signals a potential limitation in the comprehensive scope and depth of studies on SDGs within the maritime and port sectors. Such a trend of sporadic authorship intimates that the research field might be in its embryonic stages, necessitating more prolonged and synergistic research endeavours. The fact that most of the authors have published only a single time on this theme may indicate various underlying factors, ranging from the emergent nature of the subject, the challenges inherent in cross-disciplinary collaboration, to the gradually evolving recognition of the SDGs' significance in this sphere. Consequently, this observation underscores the need for an augmented focus on promoting ongoing engagement and collaboration amongst researchers, a step that is pivotal in cultivating a more detailed and nuanced comprehension of SDGs in the maritime and port industries.

The results associated with the presence of the keyword "sustainable development goals" in the articles' keywords. In total, 19 studies employed this term as a keyword, with contributions from 68 authors. Notably, Di Vaio. A has three publications, while the authors Adams, M.; Hassan, R.; Macneil, J. L.; Taneja, P.; Walker, T. R. each have two published articles. The remaining 62 distinct authors each have a single publication. From this analysis, it is evident that only 6 authors who previously published on SDGs in ports used the term "sustainable development goals" as a keyword in their articles (Fig. 7).

For the advancement of science, it is imperative to encourage authors to engage in multinational collaborations. This facilitates knowledge sharing and its application across diverse contexts, pooling essential resources for successful project development (Del Giudice et al., 2022). From the evaluation of the selected articles, it was determined that out of 32 research papers, 16 employed the case study as their methodological foundation, connecting ports and SDGs in 27 unique countries. Consequently, the specific ports, countries, and continents addressed were identified (Fig. 8).

In the research conducted by Caliskan (2022), a comprehensive examination encompasses Belgium, Italy, Germany, and the Netherlands. Contrarily, in the study articulated by D'Amico et al. (2021), Italy remains the sole exception among the quartet. Notably, nations such as

Indonesia, Sri Lanka, Brazil, and Ukraine appear to be devoid of interconnections either among themselves or with other countries, each being singularly addressed in distinct academic inquiries (Table 3 and Fig. 8).

4.1. Rotterdam

The European continent stood out with the highest number of ports, with a total of 51 of the 66 presents in the 16 papers. In second place is the Asian continent, with 8, in third is South America, with 5, and in fourth place is North America, with 2 ports (Table 4). The European continent highlights port performance based on sustainable practices and transparency of information from ports in Europe.

Analysing the countries of the 16 papers (see Table 4), Belgium and Italy were highlighted, present in four studies respectively (Caliskan, 2022; Cavalli et al., 2021; Cerreta et al., 2020b; Cerreta et al., 2020a; D’Amico et al., 2021; Fedorenko and Khmeleva, 2021; Michalska-Szajer et al., 2021) and Germany and the Netherlands in three respectively (Caliskan, 2022; D’Amico et al., 2021; Michalska-Szajer et al., 2021; Taneja et al., 2021).

Belgium has several relationships, such as with Germany, Switzerland, Greece, France, Spain, Italy, and Russia (Fig. 9). Germany differs only in relation to Russia, a country that has no connection with other countries (Fig. 9). With this, the connection between Belgium and Germany is observed in the studies (Caliskan, 2022; D’Amico et al., 2021; Michalska-Szajer et al., 2021).

The direction of the sectors studied in contributing to the SDGs is observed due to the increase in research by 25% in the period 2020–2022, demonstrating the tendency of publications on the subject. However, it is worth noting that in most of the studies guidance was perceived only in some SDGs, mainly in those that are aligned with the needs of each context. As a result, the scope of the sector’s contribution

Table 4
Study ports classified by continent.

Asian	Europe		North America	South America
Colombo	Algeciras	Livorno	Los Angeles	Imbituba
Hambantota International	Aliaga	London	Montreal	Itajaí
Hanian	Ambarli	Marseille		Itapoá
Klang	Amsterdam	Medway		Navegantes
Mafa	Antwerp	Mersin		São Francisco do Sul
Singapore	Barcelona	Milford Haven		
Tanjung Carat	Bergen	Naples		
Tanjung Pelepas	Bilbao	Oktyabrsk		
	Botas	Piraeus		
	Bremerhaven	Riga		
	Constanta	Rotterdam		
	Dunkerque	Sines		
	Felixstowe	Souda		
	Gdansk	Southampton		
	Gdynia	Stockholm		
	Genova	Swinoujscie		
	Goia Tauro	Szczecin		
	Gothenburg	Tallinn		
	Hamburg	Taranto		
	Immingham	Tees & Hartlepool		
	Iskenderun	Trieste		
	Kocaeli/Izmit	Valencia		
	La Havre	Vladivostok		
	La Spezia	Wilhelmshaven		
	Las Palmas	Zeebrugge		
	Liverpool			

to the SDGs is still limited.

It was also possible to identify the main journals that are aligned with the publication of the theme, with *Sustainability* of Swiss origin being the one that stood out the most in terms of the number of articles published. This analysis facilitates the tracking of researchers by journals that are linked to publications on SDGs in the maritime industry and the port sector.

Likewise, it was noticed that half of the sample (16) has the case study as a methodological basis, analysing specific port contexts, with a focus on developing sustainable practices aimed at meeting the SDGs. However, in most of these surveys, actions were not linked to specific SDGs, to effectively detail how each action is aligned with the SDGs, and thus serve as a parameter for other contexts.

The studies related to the initial years of the sample (2017–2018), for the most part, carried out comprehensive analyses, not clarifying how the maritime and port industries significantly contribute to the SDGs. In addition, no related publications were found in 2019. In recent years (2020–2022) there is a greater trend of publications linking sustainable port practices and SDGs.

Regarding the continents, European was observed as the focus of research and comparative analysis, with the ports studied being considered as benchmarks for sustainable practices. It also pointed out the strong direction of the publication of non-financial reports by the ports belonging to that continent, as analysed in Caliskan (2022), reinforcing the effective transparency with the interested parties.

5. Conclusions

This paper, grounded in the methodology of bibliometric analysis, sheds light on the emerging focus on the United Nations Sustainable Development Goals (SDGs) within the maritime and port sectors. Through an in-depth examination of keyword analytics, this study identifies key themes and exposes the complex nature of sustainability in port operations, as revealed through the interplay of keyword relationships. A notable aspect of the selected case studies is their high-light on international collaborations, which underscores the intricate global interdependencies inherent in the maritime sector.

Building on this foundational understanding, the manuscript provides a thorough overview of the current alignment between port management practices and the SDGs. It underscores the essential role of transnational collaborations in promoting sustainable practices. Utilizing network visualization maps, adept at extracting and analyzing keywords from academic abstracts, the research underscores terms that frequently arise and form strong connections. Notably, the terms “sustainable development goals” and “port” hold central positions in this discourse. For instance, “sustainable development goals” show extensive connections with concepts such as “port management”, “city port model”, and “circular economy”, while “port” is closely linked to “circular economy”, “blue economy”, and “energy efficiency”.

In evaluating the research outputs, associations with terms like “port city model”, “circular economy”, “blue economy”, and “energy efficiency” highlight dominant research directions. The intersection of economic growth and environmental sustainability emerges as a pivotal challenge in aligning the maritime and port sectors with the SDGs. The recurrence of terms such as “circular economy”, “blue economy”, and “energy efficiency” underscores the imperative for significant investments in clean technologies and sustainable operational practices, thereby challenging traditional business models. Moreover, the effective integration of sustainable development strategies necessitates a holistic approach that extends beyond port operations to encompass associated supply chains and logistics, consequently broadening the scope and intricacy of the endeavors required to actualize the SDGs.

In reflecting on the scope and limitations of this study, it’s worth noting specific considerations. The research primarily drew from the Web of Science and Scopus platforms, and while these are reputable sources, other databases might offer additional insights. While aiding

focused research, the specificity of the chosen keywords might inadvertently exclude articles with synonymous terms or varied phrasing. Moreover, though intentional, the decision to focus on publications from 2017 and beyond means that initial dialogues or studies immediately following the 2015 introduction of the SDGs might not be encompassed within this review.

Envisaging future research trajectories, this study advocates for a more expansive exploration of SDGs, fostering collaborations across diverse geographical landscapes and probing into relatively uncharted territories like the Americas and Africa. Ultimately, this research endeavours to serve as both a reflective lens capturing the extant scholarly landscape and a directive, spotlighting existing knowledge gaps and delineating avenues for ensuing academic inquiries predicated on comprehensive content analyses and bibliometric insights.

CRediT authorship contribution statement

de Santana Porte Marcelo: Conceptualization, Data curation, Software, Writing – original draft, Formal analysis, Visualization. **Mendonça Oliveira Clóvis Bósco:** Conceptualization, Writing – original draft. **Viana Diniz Natalia:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Cunha Darliane:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing, Software. **de Freitas Fernandes Fernando:** Conceptualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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