

A Comprehensive Review of How Port Infrastructure Contributes to Sustainable Development Goals

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Abstract

This paper will show a full systematic literature review study of the research study on how port infrastructure fosters sustainable development. With the rise in international trade and the pressures being exerted on the environment, the ports have become key hubs towards the attainment of the sustainability goals. The review summarizes the evidence of a number of empirical and conceptual studies to determine the role of ports in terms of environmental stewardship, economic resilience and social equity. Some of the most important themes are energy efficiency, reduction of emissions, green logistics, and engagement of the community. The discussion identifies the contemporary issues, emerging approaches, and policy frameworks towards sustainable operations of port systems. The paper also comes up with research gaps of the current literature and provides new research directions that should be counted by incorporating cross disciplinary research.

Keywords: Port infrastructure, sustainable development, green logistics, environmental impact, maritime sustainability, emissions reduction, circular economy, port governance, eco-efficiency, global trade.

1.Introduction

In the modern world of rising environmental challenges, increased global urbanization and the frantic reminders of the importance of United Nations Sustainable Development Goals (SDGs), the issue of port infrastructure has taken a central place as the means of making global environment sustainable. Because of the greater roles that ports play in the global trade and other logistics networks as being key hubs in the realization of economies, ports are no longer regarded as mere entry points to correct economies but rather being speculated as potent agents in establishing the course of ecological responsibility, socio-economic inclusiveness, and governance innovation(1). This paper will look in a systematic manner at how port infrastructure is aligned to, contributing to, and supporting the development to the SDGs, especially through technological development, policy changes, and stakeholder integration into the port system.

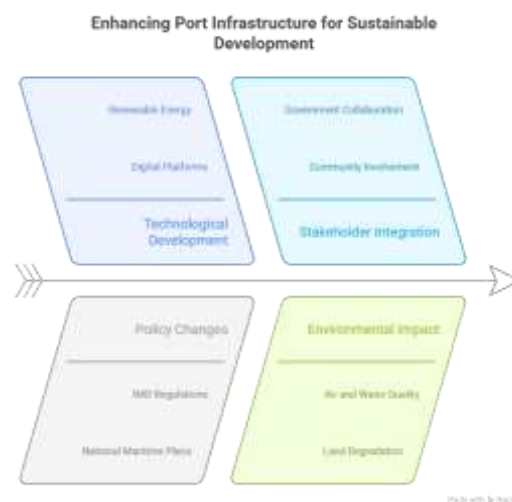


FIGURE 1 Enhancing Port Infrastructure for Sustainable Development

The port infrastructure concept includes a broad range of both physical assets, management systems and operational frameworks which, combined, serve the maritime trade and multi modal logistics. These infrastructures are the terminals, the container yards, the transportation linkages, the energy supply system and the digital platforms which are efficient in the operational and facilitation of trade. Nevertheless, the coastal environments, the urban integration, air and water qualities, and the local economies are largely affected by these

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same systems. Therefore, going green has ceased to be a choice only; it is a strategic requirement. Ports need to transform into sustainable multimodal centers involving the engagement of renewable energy, facilitating the circular economy, and adopting eco and social-friendly operation strategies.

The Sustainable Development Goals were developed by the United Nations in 2015 as a common framework that guides every member of the world community on how to overcome poverty, conserve the earth, and make sure that prosperity is available to all(2). The SDGs contain 17 goals, 169 specific targets, which is a multidimensional framework in relation to which the activity and achievement of port systems can be evaluated. A number of the SDGs are of particular concern to port infrastructure- including SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 14 (Life Below Water). Successful ports can be affected directly by providing energy management, cutting down emission, and inclusion of communities within the community. This has in turn seen the port authorities, governments and maritime stakeholders compelled to ensure that their strategic development agendas keep in line with global sustainability goals.

Historically the agenda of port development took the form of capacity addition, competitive throughput and cost-effectiveness. Nevertheless, this legacy model has resulted in significant environmental externality i.e. air pollution in ship and cargo equipment, land degradation owing to the expansion, highway congestion in the hinterland areas, and notable carbon emission. In recent years, the number of ports adopting the decarbonization roadmaps, electrifying their operations, and implementing green technologies, including shore power and alternate fuels, increased. Such endeavors indicate a more comprehensive policy shift of strategic reorientation to sustainability of the port development policy as well as the infrastructure investment.

The International Maritime Organization (IMO) which is the international regulatory arm of the maritime industry is very instrumental in forging sustainable port practices such as the MARPOL convention and the 2030 agenda of sustainable development. In addition, reflective regional initiatives like the European Unions Green Deal, the Asia-Pacific port alliances, and national maritime plans are incorporating the SDGs in planning frameworks of ports. As diverse technological advancements, including digital twins, AI enhanced logistics optimization, smart grids, and blockchain trainer environmental compliance, have changed the pattern of measuring, monitoring and managing sustainability in port operations(3). The above developments are pointing to a situation where the role of port infrastructure must be considered in a sustainability approach, beyond an engineering focus, to assessing its contribution level at the governance, stakeholder participation, and social inclusivity levels.

The background of this review is based on the fact that an overall synthesis of academic literature and policy evaluations on the role of port infrastructure in facilitating a sustainable development was required. Derived through a systematic literature study in the databases of Web of Science, Scopus, or local repositories, the paper classifies the corpus body of literature by methodology (quantitative/qualitative/theoretical/ mixed methods), thematic orientation (environmental/economic/social/governance), and geographical distribution. One of the major objectives is to delimit dominant trends, gaps, and desirable practices in the port sustainability assessment models.

In addition, the study focuses specifically on passenger ports, which are often excluded due to cargo-oriented research, by assessing their sustainability pledges in a form of annual reports, port master plans, and stakeholder statements. Since passenger ports converge with city processes, the tourism sector, and the provision of basic services to people, they are at a vantage point in which they can shape the sustainable development at the community level. The paper has also included a case study of major European harbors like Helsinki, Tallinn, and Dover, which are evidence of progressive sustainability models and orientation with regard to SDGs in accordance with climate action, community involvement, and digitalization.

Notably, the approach of the following research is grounded in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, which guarantees both transparency and replicability and analytical depth. Time frame 2012-2022 During their research, the authors have accessed studies of previous years, which has made it possible to perform a time analysis to determine the trends in evolution of sustainable practices and sustainability in port structures over the last decade or so(4). The discussion points to the emergence of ports moving beyond single green efforts into broader approaches of the integration of sustainability into the systems operations of ports, the importance of interdisciplinary methods and integrated governance arrangements, and systems of innovation.

This paper is a contribution to both the academy and the policy. Academically, it develops a multidimensional perspective on a sustainable port infrastructure that synthesizes scattered interdisciplinary knowledge on the fields

of engineering, environmental science, logistics and public administration. In practice, it can be used by decision-makers, port authorities, investors, and sustainability officers to provide them with a unified picture of success factors and strategic levers that they may maximize their contribution to the SDGs. Further, the article also charts out a future study agenda that will delve more into the indicators of sustainable infrastructure, digital sustainability measure and community involvement in the process of port governance.

2.Role of Port Infrastructure in Advancing Sustainable Development Goals

With the highest regard given globally to sustainable development, the academic guidance has reacted with a heavy jump in the academic research analysing the multiple faculties of port infrastructure in the attainment of the Sustainable Development Goals (SDGs). This segment critically appraises the range and level of academic input on the same in the last ten years with a particular focus on the manner in which port infrastructure has been conceptualized and measured as an engine of environmental stewardship, economic resilience, and social equity. Through a well-guided approach as recommended in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), this assessment organizes the literature according to three main axes, which include the thematic approach, the methodology, and the geographical location. The articles considered were identified on the basis of the Web of Science Core Collection with the publication dates between 2012 and 2022. Such combinations of keywords as sustainable port infrastructure, SDG alignment, green port systems, and maritime sustainability were used(5).

The original search revealed 112 publications, and after narrowing the field to 94 peer-reviewed articles, which directly touched upon the point of combining the port infrastructure with the ideas of sustainable development goals. These were grouped into the research areas such as technical-technological innovations, administration and legislative framework, socio-economic incorporation and environmental impact analysis. Thematic analysis showed that the scholarly background was almost entirely occupied by the environment-related issues; specifically, emissions reduction, energy efficiency, marine biodiversity were found in about 42 percent of the chosen publications. Themes about economic topics (21%) and social inclusion stratagems (13%) were next with the remaining proportion of studies comprising of governance innovation, public-private unities, and digital seaboard ecosystems.

Concerning the methodological approaches, a variety of mix was observed. The most widely applied (41 percent of the studies) quantitative models were the quantitative models, lots of them applied in the assessment of the sustainable performance using life cycle assessment (LCA), data envelopment analysis (DEA) and multi-criteria decision analysis (MCDA). Interestingly, empirical evaluation of carbon emissions, port throughput efficiency, and operation resource consumed was made possible using these methods and the case studies represented by Europe, Asia, and the Americas(6).

The second most frequent method entailed the theoretical and conceptual frameworks (31%). These articles have provided the basis on comprehending the role of port infrastructure and the road to sustainability agendas by suggesting policy frameworks, development strategies, and governing models in terms of SDGs. These cases include the planning of the strategic ports by using SDG 9 (Industry, Innovation and Infrastructure) and creating evaluation matrices that use SDG indicators to create port performance dashboards.

Less common but providing vital contribution to the perspectives of the stakeholders, behavior in institutions, and interactions between the port and the surrounding communities are qualitative methods (16%). These were the structured interviews with the representatives of the port management, surveys of the representatives of logistics operations, and focus group discussions with the representatives of the community. These studies have provided special knowledge in the sociopolitical phenomena of sustainable port development particularly in the contexts where there exist clashing interests of commercial growth and protection of environment.

A total of four studies (about 4 percent) in the study fit in the other category, which used simulation models, GIS-based mapping of the environment, or systems combining real-time sensor records with forecasting systems. Such approaches demonstrate the new direction of digitalization and “smart” sustainability evaluation of port infrastructure investigation.

Geographically, production of research was also focused in Europe (especially in the Netherlands, Spain, Italy, and the UK) and Asia (first of all in China and South Korea) due to a robust maritime economy and a policy commitment to sustainability. North America came closely behind whereas Latin America, Africa, and Southeast Asia were underrepresented in the literature- even in regards to their large exposure towards maritime trade and

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infrastructure development requirements. Such a geographical disparity is an indication of a greater need to have more inclusive and regionally diversified research effort with consideration to changeable socio-economic circumstances and development orientations.

Another trend that can be spotted in this literature is the growing importance placed on sustainable combined frameworks, the non-isolated view of ports, that is, as key supply nodes within the regional supply lines, urban environs, and national climate management plans. Such a transition indicates an emerging agreement that sustainability of port infrastructure should move beyond technical renewals and embrace the concept of a circular economy, social responsibility, and policy integrity(7). Standardised metrics of sustainability The lack of standardised sustainability metrics, including port sustainability indexes that aggregate environmental, social and governance (ESG) indicators into benchmarking instruments also are called within the research community.

Decade of Sustainable Port Infrastructure Research



FIGURE 2 Decade of Sustainable Port Infrastructure Research

The other interesting fact is that there has been a slow but steady emphasis on passenger port infrastructure particularly in Europe. Of these 34 articles, a subsample was selected, which focused on the way cruise terminals and ferry ports embrace the elements of sustainability in their operations. These are innovations in waste management, sustainable tourism nexus, energy efficient terminal buildings and multimodal transport access. As was noted in the research, although container terminals tend to gain more policy and scholarly coverage, passenger ports have a distinct advantage, since their high visibility and frequent contact with the general population allow these ports to affect both the local population and transnational sustainability commitments alike.

On the whole, such assessment demonstrates a substantial and increasing body of research which can support the importance of port infrastructure as strategic choices in SDGs progress. Yet, also noted in the discussion are some critical gaps in the literature (1) lack of integration of the social equity and community development perspective; (2) fewer studies with long-term longitudinal designs of sustainability performance; and (3) insufficient inclusion of low-and-middle income countries (LMIC) in the empirical studies.

One task of the future research would be to focus on engineering, policy studies, economics, and sociology and build comprehensive models of the sustainable port infrastructure in terms of transdisciplinary research. In addition, the development of collaborative platforms of academia, ports authorities and international organizations to design, implement and track transformative role of ports in the accomplishment of the goals of global sustainability agenda will be a very fundamental mandate.

3.Methodological Approaches in Port Infrastructure Research

To apprehend the role of port infrastructure in the promotion of Sustainable Development Goals (SDGs), one must examine the methodologies that were used by the scholars researching this complicated field of interactions between the domains of logistics, technology, environment, and governance. The identified studies in the studies reflect the multidisciplinary environment of the sustainability studies within the maritime infrastructure; a characteristic that is shown by the wide range of methods used in the studies positioned along a methodological spectrum. In this section, the most popular research methods will be organized systematically in five main categories, namely, quantitative, theoretical, qualitative, literature, and hybrid or other methods.

3.1 Quantitative Methods: Data and Models as a Way of Measuring Impact

The most common of them were quantitative methodologies (used by more than 40% of the reviewed literature). Such approaches use quantitative measures of energy consumption, emissions, efficiency of throughput and financial outcomes in determining the sustainability of the ports.

Research that was based on Multi-Criteria Decision Analysis (MCDA) and Analytic Hierarchy Process (AHP) models was especially prevalent. These methods enabled researchers to prioritize sustainability indicators according to the priorities of port authorities or preferences of the stakeholders. As an example, major Asian ports have had their green performance measures evaluated with the help of AHP, whereas scenarios of infrastructure investments as per the SDG targets have been simulated with the help of MCDA frameworks(8).

Additional commonly applied methods are:

- Regression analysis in order to detect relationships between port infrastructure investment and the environmental KPI improvements (e.g. decreased sulfur emissions).
- Environmental Performance Indicators (EPIs) were applied in the benchmarking of ports among regions especially in SDGs 7, 12, and 13.
- Life Cycle Assessment (LCA) to allow quantification of the total environmental impact of port infrastructure at its construction-completion, energy nourishment, decommission, and disposal.
- A carbon footprint model used as one of the main processes under SDG 13 (Climate Action), to measure vessel activity port-related emissions and equipment at a terminal.
- Simulation models on the basis of optimization algorithm e.g., mixed-integer linear programming (MILP) are proposed to assess infrastructure scenarios with economic and ecological tradeoffs.

Such powerful and evidence-based approaches can be well-liked by policy-makers or engineers doing research to understand the patterns and powerful solutions because they have predictive qualities and empirical ability.

3.2 Theoretical and Conceptual Frameworks: Creation of Foundations of Sustainability Integration

About 31 percent of the studies employed the grounds of theory. The main aspects of these works are the development of conceptual frameworks, governance frameworks or policy strategies that connect port infrastructure and wider sustainability aims.

Some important contributions in this category are:

- Strategic planning models that integrate port development with SDGs are especially in the fields of innovation (SDG 9), decent work (SDG 8), in addition to sustainable cities (SDG 11).
- The Engagement of integrated port governance models, they examine multi-stakeholder decision-making as well as institutional emphases, which are essential port transformation components.
- Comparative policy analysis, the issue of the policy of green port implementation in various countries and a regulatory environment associated with such transitions.
- System thinking and resilience models that give comprehensive picture of the operation of the ports and how they are at risk to both environmental and economic jolt.

Application of these theoretical models forms the essence of providing translations of abstractness language utilized in SDGs into operational plans to suit specific port operations, particularly to achieve regulatory convergence and long-term plans.

3.3 Qualitative Techniques: Human Dimension and the behaviour of Institutions

Although much less commonly applied (approximately 16 per cent of the studies), qualitative methodologies can provide invaluable information concerning social, organizational and institutional aspects of port sustainability. The two methods specifically comply with SDG 16 (Peace, Justice, and Strong Institutions) and SDG 17 (Partnerships for the Goals).

Popular methods of qualitative studies are:

- Semi-structured interviews with port management, terminal operating companies, policymaking authorities, and community members to be informed about their opinions of any sustainability efforts or infrastructure developments.
- Surveys or questionnaires inquiring into topics like the participation of employees in the green operations of the port or community resistance to growing port and/or awareness of port-based SDGs.
- Delphi panels and focus groups had been implemented to seek expert opinion about new technologies or strategic priorities in the sustainable infrastructure.

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This type of studies is paramount in locating social opposition, loopholes of policy application, or a clap-back between economic improvement and preservation of the environment. They also contribute to the discussion of equity, inclusivity and labor practice which are the aspects that are not much commented on in technical assessment.

3.4 Structured Literature Reviews: Interdisciplinary synthesis of knowledge

The coming decade will further see the convergence and fusion of knowledge as it continues to be produced to solve practical problems in the society(9).

Literature reviews have been important in integrating previous knowledge and where missing empirical data abounds. Such reviews frequently applied systematic procedures such as PRISMA to guarantee in transparency and replicability of the process of selecting and analyzing articles.

These studies indicated, by the use of content analysis, bibliometric mapping, and clustering of key words the following:

- The SDG distribution where some SDGs are more popular (e.g. SDG 13, SDG 9) and others remain comparatively less discussed (e.g. SDG 5 (Gender Equality) or SDG 4 (Quality Education)).
- The imbalance of the research in terms of the geographical location, as high-income countries dominate academic activity.
- the time-series demonstrating a historical change towards a new paradigm of sustainability instead of single-issue environmental research (e.g., air pollution) in recent years.
- Such literature reviews not only aggregate research which is disjointed, but they also point out conceptual and geographical blind spots that empirical research should spread light on.

3.5 Hybrid and Emerging Methods: To Smart Data-Driven Sustainability

A much-reduced crop of studies (about 12 percent) used hybrid or emergent approaches which integrate established methods and sophisticated tools. The approaches relate to the increasing impact of digitalization and real-time data analytics on port sustainability.

Examples include:

- Smart ports with dashboards connecting sensor data, weather conditions and traffic flows to report on real-time emissions.
- Carbon offset project verification systems that use blockchain reporting to verify the integrity of carbon offset projects or ways to keep track of the environmental footprints of cargo.
- Mapping of ecological zones with geospatial information systems (GIS) where the ports could be constructed or dredged.
- Machine learning models that forecast traffic congestion, the use of berths or emissions scenarios in differing operation patterns.

The solutions that the tools provide, in terms of infrastructure sustainability, are scalable, repeatable, and flexible, which fits within the current trend of the smart port paradigm following 2020. They specifically apply to ports that are seeking to work on SDG 11 (Sustainable Cities), SDG 13 (Climate Action) and SDG 14 (Life Below Water).

4. Discussion

With the world becoming more and more engaged in sustainable development causes, the development of a port infrastructure is the sphere that receives an increased level of control and analysis based on the principles of the United Nations Sustainable Development Goals (SDGs). The review highlights the fact that ports are no longer stationary transport nodes but are fast being transformed into highly functional nodes requiring a balance between economic performance and environmental protection as well as social responsibility. Their role in SDGs is complex: to mention a few, they contribute to the SDG of clean energy (SDG 7), to industrial innovation (SDG 9), to sustainable cities (SDG 11); and they directly relate to climate mitigation (SDG 13), and marine life sustainability (SDG 14). This revolution can be seen to go beyond the actual designation of port infrastructure, but also to succeeding operational philosophies and governance structures that define port development in the 21 st century.

The review illustrates the overwhelming inclination towards quantitative approaches to assessing the sustainability of ports, which can be considered the tendency in the analysis of the infrastructure and engineering systems in general and preference of the data-based results. Such techniques as multi-criteria decision analysis (MCDA), analytic hierarchy processes (AHP), and life cycle assessments (LCA) enable those involved in research to create

accurate models of assessments of emissions, energy efficiency, and throughput based on ports that align with particular SDGs. Nevertheless, these methods are very helpful in gaining insight, especially since they provide a clear understanding of abundant knowledge. However, this kind of learning does not always include the human, behavioral, and institutional background that is necessary to make the sustainability efforts actually valuable and locally applicable. Most of the crucial dimensions, including community involvement, labor standards, governance quality, and socio-political opposition, are understudied or inadequately studied as a result. The absence of the integration of technical evaluations and social-economic realities constitutes an obstacle to total and inclusive sustainability planning within the port development(10).

Geographic skew in research output is another essential fact of this review. The majority of sustainability studies regarding port infrastructures are found in regions that are economically developed like the regions of Western Europe, East Asia and North America, where there is a relatively mature regulatory framework, funding options and technological facilities. They also exhibit superior institutional systems which favour sustainability requirements and have more uniform access to data reporting and transparent systems. On the contrary, the ports in the offshore states with developing and transitional economies, which are on a higher environmental and social risk scale because of the high rates of urbanization and industrial boom, are largely under-reported in academia. Not only does this disparity hamper cross-national knowledge on the topic of port sustainability but it also serves to create an asymmetrical dispersal of innovations and best practices. It also stresses the necessity in including more collaborative research ventures and capacity building initiatives that will enable ports in the Global South to be involved and even benefit in the sustainability transitions.

Although there has been more prominence of the SDGs in the strategic port discourse and national transport plans, it has been identified that there has been a lack of commitment between the proclaimed and actual practice. The analysis of the annual sustainability reports prepared by the largest European passenger ports reveals the majority of ports refer to the SDGs and sustainability agendas yet without the introduction of any detailed monitoring indicators and accountability mechanisms and/or 3rd -party verification. The visibility-performance gap suggests that not all ports might be performing sustainability as part of reputation maintenance process but as an operation of the highest priority. To resolve that, we require setting standardized frameworks of sustainability reporting, promotion of third-party auditing, as well as the implementation of sustainability indicators in port performance evaluation. It is during transparent, consistent documentation that real progress towards SDGs can be finally tracked, benchmarked as well as improved over a period.

One of the significant opportunities found in the literature reserves the growing contribution of digital innovation to the provision of sustainability. The technologies that are smart ports such as the Internet of Things (IoT), blockchain systems, AI-powered logistics systems, and environmental modeling with the use of GIS, are changing how ports are managing their data, emissions monitoring, and vessel traffic control, and how to best go green in terms of minimizing waste. Such technologies promote real-time decision-making, resource efficiency, and they have a direct contribution to SDG 9 and SDG 13. Nevertheless, the assimilation of these technologies is not steady, and in many cases, it is hampered by expensive implementation slowing the process, absence or inaccessibility of digital infrastructure, and even shortage of technical skills as well, particularly within the smaller ports or the less-developed ports. Moreover, although digitalization is a new hope of enhanced efficiency and sustainability, it also introduces such issues as the displacement of its human workforce, data privacy, and cyber-resilience which need to be tackled with the help of comprehensive planning and the policies of digital governance.

Lastly, the review indicates that there is an urgent need to have a standardized format of a multidimensional sustainability concept model of its requirements on port infrastructure. The recent assessment methods tend to be piecemeal- assessing environmental performance or economic growth in isolation, or social responsibility-without providing the complete picture representing how sustainability issues have links with both other issues and solutions. The type of framework is expected to unite both quantitative measures (e.g. emissions, use of resources and materials, logistics throughput), qualitative measures (e.g. involvement of stakeholders, quality of governance, social impact), and spatial-temporal aspects (e.g. short vs. long-term effects, local vs. global implications). In addition, this framework must be flexible over port types such as cargo, passenger, and mixed-use; and responsive to regional differences in resource endowments and policy and developmental priorities. In case of such a tool, policy makers, port authorities and researchers would be in a better position to design, implement, and assess strategies to make the port infrastructure a pillar of sustainable development and not an ecological and social burden.

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In sum, the discussion has indeed verified that port infrastructure can be a strong facilitator of the Sustainable Development Goals, though its transformational power can only be exercised when sustainability becomes embedded in a systematic way in the planning process, its operations, governance, and the interaction with the community. Although there has been improvement especially in adoption of green technology and the level of emissions measurements, there are still major lapses in terms of equality, inclusion, openness, and universal access. The global response must be well-coordinated and cross-sector collaboration, integration of the subject matter into the policy-making process, and interdisciplinary research will be the factors necessary to make sure ports will be the catalysts of the trading processes and economic growth and will also contribute to a more sustainable and fair world.

5. Conclusion

This developmental review goes along to appreciate that port infrastructure is a key and continually growth factor in furthering the United Nations Sustainable Development Goals (SDGs) as a stimulator as well as a vehicle of international sustainability goals. Modern, far-stretched indeed industrial institutions, ports are getting entangled within the wider socio-economic and environmental structures and networks, besides translating to better global trade (efficiency), toward low-carbon transition and resource circularity, and growing, inclusive urban centers and cities. The results of this review underline the vastness of the scholarly involvement in the environmental, economical, and the governance levels with the evident predominance of the quantitative methods focused on quantifying emissions, energy consumption, and port performances. Meanwhile, there is a clear deficiency in the linking of social equity, institutional actions and engagement of stakeholders aspects that are central in a just and comprehensive mechanism of sustainability. The regional inequality in research, especially the poor representation of developing regions also illustrates the imbalance in the global ability to make decisions and assess port related contribution to SDGs. Although smart technologies and digital infrastructure have widened the set of possibilities governing surveillance and optimization of sustainable operations, it has been shown that inclusive policy environments, human capital, and accessible financing structures are the key to its successful implementation. This review further brings out one significant loophole between rhetorical claims of sustainability and the actual practices being implemented as seen in the inconsistent usage of sustainability indicators in ports reporting and system of accountability. In a bid to reduce this disparity, the global port community must come up with standardized and multidimensional assessment schemes, which combine technical performance and good governance (transparency, social inclusion, and economic sustainability and resilience in the long term). In addition, future studies require the need to advance out of disciplinary silos to adopt transdisciplinary approaches that have the potential to explain the complexity of sustainable port infrastructure. In exploring how ports will be important drivers of sustainability, the main question is not whether technology will involve them in that journey, but how a new form of visionary leaders, collaborative governance, and a common interest in inclusion will characterize the future of sustainability. The paradigm to face is not the modernization of ports alone, but the redesign of the port of the future as an agent of transformation and sustainable development that supports and promotes progress in the extreme of the whole range of the SDGs.

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Conflicts of interest

The authors have no conflicts of interest to declare

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