

Adoption of Sustainability in Seaport Infrastructure: A Systematic Literature Review

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ABSTRACT

The objective of the research is to analyse the sustainability measures that can be undertaken in the seaport infrastructures. The study is based on systematic literature review. The scope of the research is qualitative and may serve as a basis for identifying factors that can contribute to the adoption of sustainability in the seaport infrastructure sector. The article has direct implications for seaport infrastructure providers. They are encouraged to regularly monitor and to build climate resilient seaport (hereafter 'port') infrastructure as it is crucial for the economic growth of many developing and emerging countries, as the majority of global trade is done through sea mode. The article collates and examines recent seaport infrastructure study findings. It presents a comprehensive, conceptual model encompassing research work and a holistic view of various aspects affecting sustainability of seaport infrastructure. The article develops a conceptual model that needs to be confirmed empirically.

KEYWORDS

international Developmental Financial Institutions (iDFIs), Nature Based Solutions, Public Private Partnership (PPP), Risk-Return Matrix, UNSDGs, Sustainable Gap Funding

1. INTRODUCTION

Sustainability means enduring far into the future, and it refers to systems and processes that are able to operate and persist on their own over long periods of time (Robertson, 2021).

According to the American Association of Port Authorities (AAPA), port sustainability is defined as strategies and activities that meet current and future needs of port stakeholders while protecting and sustaining human and natural resources. Although ports contribute to the economic development of the region, they also impact the environment and thereby have an adverse impact on local communities.

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Therefore, sustainable initiatives during the development of port infrastructure and port operations are being emphasised. Sustainability considers social, economic and environmental issues, whereas green is solely focused on environmental issues (Ashrafi et al., 2019, 2020).

The purpose of this study is to understand sustainability elements and the measures that can be undertaken with the active participation of all stakeholders to improve the adoption of sustainability in port infrastructure. The study primarily explores the way various sustainable parameters can be included during the project planning and design stages of the development of port infrastructure.

2. LITERATURE REVIEW

The topic of sustainability and its applications in various industries has gained importance in the last decade. Sustainability in the seaport sector has also attracted attention among researchers. There are numerous literatures on sustainability issues and the importance of sustainability in the seaport structure. The articles were collated with a search through keywords and reviewed. The initial inference drawn from the articles were that:

- Sustainability adoption is an important consideration of all countries following the UN guidelines of 17 Sustainability Goals.
- Building seaport infrastructure is crucial to trade and commerce.
- Emerging economies, particularly in Asia, are focusing largely on building port infrastructure to promote trade.
- In building port infrastructure, the need for sustainability inclusion is gaining importance to preserve the fragile ecosystem.
- There are challenges in adopting sustainable parameters while developing such infrastructure.
- The role of key stakeholders is crucial in sustainability adoption.

Most literature on the subject highlights either the environmental or the social issues encountered in the seaports. Research on economic issues mostly centres around the analysis of funding for creating seaport infrastructures. There are also numerous research articles on the operational aspect of seaport management and linkages with sustainability dimensions through case study approaches. All these studies contributed to identifying key areas that are pertinent in the adoption of sustainability in seaport infrastructure.

2.1 Seaport Infrastructure Overview

Ports are crucial infrastructures that facilitate trade and commerce. The three stages in port development are the planning stage, the construction stage and the implementation stage. During the project planning stage, the roles of engineers and design experts are crucial. In the construction stage, project developers, financiers and local population are the key players. During the project implementation stage, key stakeholders are the port authorities, concessionaire (in case of a public-private partnership set up), financiers and the project implementing agencies.

2.2 Sustainability of Seaport Infrastructure

The port industry faces increasing challenges in addressing societal and environmental considerations while at the same time having to provide adequate capacity and cost-effective services to traders and associated industry clusters (Haezendonck & Langenus, 2019). These challenges stimulated the development of concepts such as ‘green ports’ with the key objectives of balancing environmental challenges and economic demand (Bergqvist & Monios, 2019) and striving to establish sustainable ports by increasing both their economic and environmental competitiveness. With increasing socio-

economic and environmental pressures, port authorities are taking various measures to improve the sustainability of port operations (Hossain et al.,2021).

The three independent variables identified and this study focuses on the following independent factors:

- (i) **Social Equity**
- (ii) **Environment Protection**
- (iii) **Economically Sustainable**

In reviewing a substantial number of documents and publications on the subjects, research gaps have been identified to help in selection of the research variables that are most pertinent to the subject. The current study tries to highlight the importance of sustainability adoption in the planning and design stage of seaport infrastructure development. The focus in the conceptual stage of development of infrastructure, along with the analysis of independent variables, is expected to facilitate adoption of sustainability and pave the way for further research regarding effective implementation.

In a systematic review of the relevant literature regarding the factors that impact the adoption of sustainability in seaport infrastructure, the below questions will be evaluated for the study:

1. How do we improve social equity to implement sustainability in seaport infrastructures?
2. How can environmental concerns be addressed while developing seaport infrastructures ?
3. How can the seaport infrastructure developed be economically sustainable?

The study has the following objectives:

1. To identify factors that can contribute to the improvement of social equity while building seaport infrastructures.
2. To identify mitigations that help lessen the environmental damage that is associated with seaport infrastructure.
3. To examine how seaport infrastructure developed can be economically sustainable.

The above questions and objectives clearly identify the below factors in understanding adoption of sustainability in seaport infrastructure.

3. METHODOLOGY

This research aimed to identify and analyze the factors that contributed to the adoption of sustainability in seaport infrastructure. To achieve this objective, a systematic approach that combined literature review and qualitative analysis was employed. The methodology encompassed the identification of key findings and research gaps from existing studies conducted between 2016 and 2022 within the context of seaport sustainability. The research framework was rooted in the suggested areas for further analysis in the adoption of sustainability in port infrastructure.

The research design incorporated a systematic literature review to synthesize existing knowledge on sustainability measures and factors influencing their adoption in seaport infrastructure. The primary data source for this study was academic research papers, conference proceedings, reports, and industry publications related to sustainability in seaport infrastructure. The selection of sources followed a systematic and rigorous approach to ensure the inclusion of relevant and high-quality studies. Databases such as PubMed, Scopus, Web of Science, and relevant academic journals in fields such as transportation, environmental studies, and maritime economics were searched to gather a comprehensive range of literature. The collected literature underwent a rigorous review

process. Initially, a preliminary screening was conducted to exclude irrelevant or duplicative studies. Subsequently, a detailed analysis was performed on the remaining studies to extract key findings, methodologies, variables examined, and gaps identified in relation to sustainability in seaport infrastructure.

Based on the identified themes and patterns, a comprehensive conceptual model was developed. This model outlined the interrelationships between the factors contributing to the adoption of sustainability in seaport infrastructure. The conceptual model provided a holistic view of the various aspects influencing sustainability in this context.

Factors contributing to the adoption of sustainability were identified as three independent variables. Research and studies on the subject between 2016 and 2022 were reviewed to identify key findings and research gaps. The research framework is based on the suggested areas for further analysis in the adoption of sustainability in port Infrastructure.

Scope of Study: The scope of the research will be qualitative and may serve as a basis for identifying factors that can contribute to the adoption of sustainability in the seaport infrastructure sector.

4. DISCUSSION OUTCOME AND PROPOSITION

4.1 Social Equity

Generally, marine ports are the hub of economic activity and have large employment-generating potential. Therefore, a big urban cluster gradually develops near the coast. The inhabitants are exposed to climate-related risks that are more severe near the coast and thus have a critical role in project design that takes into consideration the potential risks they are subject to and frame appropriate solutions. Local communities are impacted the most in the case of loss of natural capital and thus play a crucial role in ecosystem conservation.

Social equity entails active Involvement of local communities in all stages of port infrastructure development, starting from the project design stage and carrying through the construction and to project operational stages. It safeguards the following areas:

- (a) **Employment:** Construction activities in the port and the adjoining coastal zone can result in loss of habitat for aquatic creatures, resulting in diminished fishing activities that adversely affect the livelihoods that depended on it. Therefore, these sensitive social dimensions should be considered in the involvement of local people during project design.
- (b) **Safety, Health and Well-being:** Employees and workers associated with the development of seaport infrastructures are exposed to construction activities related hazards. Adequate care needs to be ensured to check whether the safety gadgets related to the activities are used by them and safety drills are routinely conducted to make them aware of the precautions to be taken to avoid safety related issues. Communities with dwellings in the coastal zone are the ones most vulnerable to the ill effect of water pollution and natural calamities like floods and tsunamis. Therefore, port development projects should also include the construction of hospitals, recreation facilities and robust infrastructures that are naturally calamity-proof in the long run.
- (c) **Skill Development:** Special vocational training and skill development workshops for the benefit of people settled in and around the port complex will not only contribute to decent work opportunities but will also help in building awareness towards environmental protection, ensuring more active participation in the development of the region.

Outcomes/Measures: The major outcomes from the social equity considerations that contribute to the adoption of sustainability in port infrastructure are the fulfilment of Goal 8: 'Decent Work and Economic Growth' and Goal 11: 'Sustainable Cities and Communities' of the United Nations

Sustainable Development Goals (UNSDGs). Further in the context of ports, the World Ports Sustainability Program (WSP) considers the 17 UN Sustainable Development Goals as a reference for the development of ports and captures 'Community Outreach and Port City Dialogue' as a theme pertaining to social considerations.

Proposition 1: *Active involvement of local communities is a key social factor that can majorly contribute to the adoption of sustainability in seaport infrastructure.*

4.2 Environment Protection

Going green is a trend that has also caught the attention of seaport environmental management and has become a critical part of port operations. However, it would be cost effective and productive to focus on environmental considerations at the planning and design stages of port construction rather than at the operational stage.

- (a) **Coastal Protection:** To protect the coastline from floods, wave energy and storm surges, embankments and conventional engineering structures are usually created. However, green-grey infrastructure is often a cost-effective alternative with considerable environmental benefits (Ozment et al., 2019). For example, the installation of breakwaters and plantations of mangrove forests near the coast can make the infrastructure more resilient to climate risk and reduce carbon footprints.
- (b) **Marine Life Protection:** Existing lakes and coral reef restoration can create habitat for aquatic animals and opportunities for fisheries to employ local people. The aquatic flora can contribute to cleaning the water near the coast and protect the lives of aquatic creatures that are severely impacted by man-made port infrastructures created near the coast.
- (c) **Water Pollution:** Waste from the port infrastructure facility directly enters the coastal waters, defiling it. Adequate wastewater treatment facilities, port reception facilities, fishing for litter and clean up actions can reduce water pollution.
- (d) **Air Pollution:** Particulate matter (PM), Sulphur oxides (SO_x) and oxides of Nitrogen (NO_x) are the major air pollutants near the coast caused by shipping liners and port operations that include the handling of dirty (coal and iron ore) cargoes. Although air pollution cannot be completely eliminated, it can be lessened through steps like the mechanisation of cargo handling activities, adoption of renewable energy instead of conventional coal for power requirements and the use of systems that recover energy from waste streams.

Outcomes/Measures: The above environmental factors contribute majorly to the adoption of sustainability, the making of resilient port infrastructure, the contribution to the development of the ecosystem and in helping people to face the vagaries of climate change.

Proposition 2: *Integration of natural solutions and innovative green adaptation will create a resilient port infrastructure that can withstand and adapt to an uncertain future.*

4.3 Economically Sustainable

The infrastructures built in seaports facilitate trade and commerce and contribute to the economic development of the region. Generally, the quanta of investments in building such infrastructures are huge and require special build competencies. Therefore, public-private partnership models (also called landlord models) are very common wherein private investors build the infrastructure and operate it as a concessionaire before handing it to the port authorities after a fixed period, for example 25–30 years, as specified in the Concession Agreements entered into by the port authorities, the private sponsors of the project and the lenders financing the project. To ensure the economic sustainability of the infrastructure developed in the seaport, there need to be proper coordination among the key players: -Private sponsors, Seaport Authorities and the Financial Institutions funding such projects. The different priorities and interests of these stakeholders need to be aligned to facilitate adoption of

sustainability in seaports. Each stakeholders interest and possible steps that can be initiated individually and collectively are as follows:

- (a) **Sponsors/Private Developers:** The project of developing a greenfield infrastructure, or refurbishing an existing structure, is executed by private project developers or sponsors who have a high degree of technical competencies in the building of such structures. Project sponsors are driven by profit consideration and expect that high returns on their investments will compensate them for the risk and the use of their special skills of project implementation. Returns on Investments and Returns on Equity are the principal determinants that private sponsors look for when investing in such projects. Inclusion of sustainable elements while designing projects for infrastructures development will have additional fund requirement and which need not always contribute to revenue. Therefore, the cost of inclusion elements in the project cost should be financed with concessional terms by Financial institutions or provision of grants by Project Authorities. Coordinated approach by the three stakeholders to identify the sustainable elements that can be included with adequate funding mechanism will accelerate the process of sustainable adoption in seaports.
- (b) **Project Authority/Concession Authority:** The marine infrastructures are owned by public sector or private port authorities. Construction activities in the port are awarded mostly through public-private partnerships to the private sponsors after the due bidding processes have been completed. The concessionaires (private project sponsors) operate the infrastructure either on a revenue or profit-sharing basis as agreed upon with the port authority in a concessionaire agreement. Therefore, the principal interest of the Seaport Authorities is the development of infrastructures in a time bound manner with due economic considerations to cater to the need of the seaport and be remunerative in the long run. Sustainability adoption in the seaports have gained traction in leading seaports around the globe and federal governments are providing importance to this aspect resulting in renewed focus by Seaport Authorities to include sustainable elements while developing seaport infrastructures. There is clear mention of requirement of adhering to all social and environmental requirements. However more consultative approach with the involvement of experts in the sustainable field, discussion with prospective private sponsors that take up the contract for executing the infrastructure projects and collaboration with Fis/ iDFIs that evaluate the project to extend finance will ensure proper implementable sustainable elements are captured during project development.
- (c) **Financers:** Port infrastructure projects have a long gestation period and require significant capital expenditure compared to other infrastructure projects. Lenders account for 70–80% of funding for the project, and the principal criteria for the lenders are the safety of the fund deployed and a fixed return commensurate with the risk. Because of the long tenor of the project and the complex project design, most commercial financial institutions shy away from financing such projects. International and regional developmental financial institutions mostly lend to these projects. At present iDFIs closely evaluate whether their financing comply with the environmental and social safeguard prescribed in their internal documents. Although seaport infrastructure development is essential for the economic growth the likely negative impact to the ecology because of the development need to be addressed through mitigants and inclusion of sustainable elements. It will widen the space of Financial Institutions funding such projects. To reduce the gap between the funds required for the marine infrastructure development and the appetite for the Financial Institutions to invest in the area, the seaport development project have to necessarily capture sustainable elements. Projects with embedded safeguards for environment and social will meet the responsible financing criteria of lenders thereby ensuring much needed flow of investments to the growing sector.
- (d) **Innovative Financing Tools:** The seaport infrastructure development project when meets sustainability criteria can generate interests of varied financial investors and instruments.

Structured financial products like mezzanine debt or equity-linked products can attract different sets of investors. Policy level interventions can encourage private sector participation and generate confidence among lenders in funding the sector by way of Interest rate subsidies, providing technical assistance and investment grants.

Outcomes/Measures: The key outcome is to channel the required investments for building port infrastructure without sacrificing the sustainability dimension.

Proposition 3: *Integrating the interests of private sponsors, port authorities and financiers to prioritise sustainability adoption through special incentive structures and innovative financing tools. This will ensure a port infrastructure that is economically viable and bring responsible investments to the sector.*

5. FINDINGS

5.1 Critical Relationship Among Social, Economic, and Environmental Considerations in Achieving Sustainability

Social, economic and environmental sustainability are interlinked. Adoption of sustainability can only be effective when the port infrastructures are suitably designed. Most of the literature on port sustainability focuses on environmental considerations, which is an essential prerequisite to achieve sustainability. Diverse stakeholders sometimes act solo and are only concerned about their own interests. An inclusive approach wherein economic and social considerations are also factored in along with environment considerations will generate interest among these diverse stakeholders, ensuring the success of the sustainability approach in the long run. Some scholars have proposed stakeholder's engagement and inclusion in planning and executing new port projects (Jansen et al., 2018).

Currently, port authorities are initiating measures to improve sustainable adoption in seaports due to increased pressure stemming from environmental and socio-economic considerations. Most ports have emphasised the identification, mitigation and monitoring of impacts as well as improved energy management and stakeholder engagement, particularly in environmental policy development. However, many ports are still lagging behind in taking initiatives related to energy management, certification, sustainability reporting and climate change adaptation (Hossain et al., 2021).

To achieve sustainability in seaport infrastructure, there needs to be social equity, environmental protection, and economic sustainability. The paper develops the following conceptual model (figure 1) that needs to be confirmed empirically:

6. RESEARCH METHODOLOGY

The study will be geographically centred around seaports in India which are managed by federal government or the public managed seaport trusts.

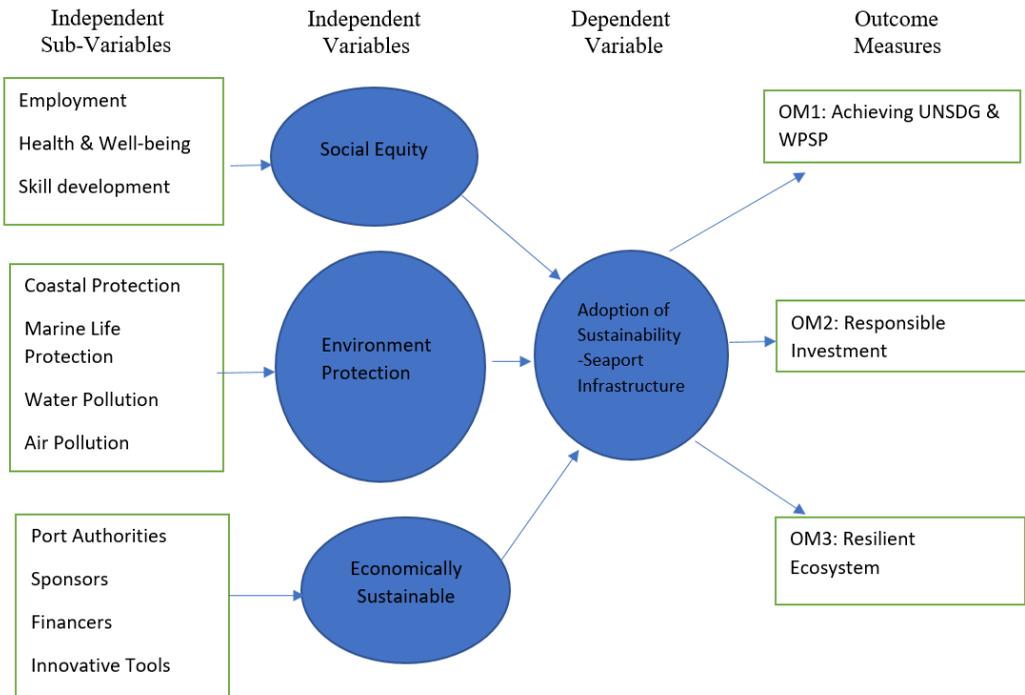
6.1 Sample

To study the practical aspect of sustainability inclusion the research will be based on a two-pronged design: -qualitative data collection approach, utilizing semi-structured interviews as well as case studies.

6.2 Data Collection: Instruments and Procedures

Sources of Data: Data will be collected from the annual reports and sustainability reports of the three entities available in their respective websites. Literature review from relevant academic journals, working papers published by eminent organizations and semi-structured interviews of select

Figure 1. Adoption of sustainability in seaport infrastructure



practitioners in the field will be the source of data collection. Use of multiple methods and multiple sources will allow for triangulation of results to increase the reliability of the findings.

Source Triangulation: Data from different sources to be compared and analyzed

Executives of Public Port Authorities (CEO/CFO/Design Engineers)

Private Sponsors executives Infrastructure specialists of Financial Institutions

Method Triangulation: -For each seaport selected for the case analysis, data will be collected through the following methods.

One to one in-depth Interviews

Focus Groups Documents/Annual Reports/ Observations

6.3 Profile of the Respondent

Potential respondents will be from from seaport corporations, financing entities, project sponsors, policy departments, environmental and social sector professionals. Mid-level and higher management staff with at least 10 years' experience in respective field will be select as sample for the study.

6.4 Sample Selection and Size

Convenience sample method will be adopted (Table 1).

6.5 Instruments and Method of Collecting Data

Instruments that will be used to collect data on topics revolving around measures to facilitate sustainable development in seaports, issues concerning adoption of sustainability and possible adoption accelerator measures are: -

- Focus Group Discussion

Respondents	Reason for selection	Sample size (min to max)
CEO / CFO/ Project Engineer of Port Authorities	Direct responsibility for sustainability adoption	10-20 assuming selection of 10 seaports
CEO/ Project Managers of Private Sponsors	They are the key to design sustainability elements during the Project design	10-20 assuming selection of 10 seaport
Finance specialist from Marine transport sector	They structure and ensure investments in the sector	5-10
Environmental Specialists	They can suggest sustainability measures feasible in the sector	3-4
Social safeguard specialists		2-3
Employees		10-20
Local population		10-20
Aggregate		50-97

- Semi-structured one to one Interviews
- Annual Reports/ Sustainability and Environmental reports available in public domain/websites of selected seaport corporations.

Data will be collected through the following processes: -

- Through virtual mode with recording facility
- Predetermined date and time
- Request for participation to be made through emails and telephone calls
- One to one interview – 5 questions with 30 minutes for a single interview
- Focus group – 45 minutes to 60 minutes, 4-5 participants

7. SIGNIFICANCE OF THE RESEARCH

Development of infrastructure in seaports has remained as a focus area for countries having access to water bodies. In emerging economies there has been a huge requirement to have in place adequate infrastructure at the seaports to cater to the increasing trade and commerce requirements through sea mode. As seaports are becoming a hub of economic activities, sustainability adoption within its premises has become crucial. Developing nations such as China, India, and Iran have seen massive growth in PPP projects and research interest in the last decade. (Rasheed, N., Shahzad, W., Khalfan, M., & Rotimi, J. O. B. (2022)

8. CONCLUSION, IMPLICATIONS, AND FUTURE SCOPE

8.1 Conclusion

Adopting sustainability in port infrastructure has gained considerable importance, particularly in Emerging Markets and Development Economies (EMDE) where, to keep pace with development, there is a growing need for the development of port infrastructures. For the port infrastructure to remain resilient for a long period and have an inclusive growth model, adoption of sustainability is a must.

With seaport infrastructure being a national asset, there are challenges with respect to the pace of responsiveness from public authorities and regulatory constraints when it comes to the implementation of sound principles that facilitate the adoption of sustainability. However, with a collaborative and participatory approach of all interested stakeholders, adoption of sustainability in port infrastructure will improve considerably in the days to come.

8.2 Implications

The paper has direct implications for seaport infrastructure providers. They are encouraged to regularly monitor and to build climate resilient seaport (hereafter 'port') infrastructure as it is crucial for the economic growth of many developing and emerging countries, as the majority of global trade is done through sea mode. The port infrastructure created should not only be strong enough to withstand the vagaries of climate change but should also have minimal negative impact on the fragile ecosystem in and around the port complex. Considering this, emphasis has been accorded to the concept of sustainability while building seaport Infrastructures. Adoption of sustainable parameters are possible only with the proactive participation of key stakeholders like the port authorities who own the port, private players who are developing the project, international Developmental Financial Institutions (iDFIs) that are financing the project and local communities settled in and around the port premises.

8.3 Sustainable Gap Funding

Adoption of sustainability in port infrastructure involves the integration of efforts from all key stakeholders at the planning and design stages of seaport infrastructure. Although all key stakeholders have a common interest in sustainability adoption, roadblocks are encountered when creation of a particular infrastructure such as a breakwater, water treatment plant or aquatic park within the port complex have no investors. The stakeholders shy away from assuming responsibility of ownership, financing, maintenance and upkeep of such structures. Therefore, a Sustainable Gap Fund (SGF) can be created with the initiative of federal governments wherein port authorities, private sponsors, financiers and federal governments can be associated, wherein respective stakeholders' responsibilities will be spelled out, and the fund can be used to fund sustainable infrastructures within the port premises. Involvement of the local population in the upkeep and maintenance of such structures can be encouraged and will help maximise sustainability adoption in port infrastructure.

8.4 Limitations and Scope for Future Research

The paper develops a conceptual model that needs to be confirmed empirically. Secondary data, limited to a few research papers and articles, were employed. The study is limited to three independent variables, however, other important independent variables like climate change, innovation and technology can be considered separately. Future research can focus on inclusion of soft infrastructure in the overall adoption of sustainability in port infrastructure. While financing port infrastructure, soft infrastructure can be considered. Soft infrastructure consists of credit rating agencies, financial regulators, capital markets participants, transparent procurement, policy makers, etc. Focus on these soft infrastructures can lead to institutional sustainability which will further contribute to adoption of sustainability in the seaports.

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