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Sustainability Performance Assessment Framework for Major Seaports in India

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ABSTRACT

In performing seaport operations, triple bottom dimensions and its related key performance indicators play a significant role in improving overall aspects of seaport sustainability. This research paper intends to examine key seaport practices that form sustainable seaport development in the Indian major seaports context from stakeholder collaboration and seaport internal sustainable management decision framework. Firstly, the key practices of sustainable seaport development were examined through a broad literature review considering sustainable seaport development and related management and stakeholder-based theories. Sustainability thematic analysis is carried out based on the identification of various dimensions and key performance indicators from various literary works. Based on the theoretical framework seaport sustainability conceptual model was developed. Semi-structured interviews were conducted with 87 seaport professionals and FAHP was performed on an input basis by 23 seaport authorities to analyze the prominence of the proposed sustainable seaport development dimensions. This study also indicated that the economic dimension is the most important, while the social dimension is the least vital dimension perceived by Indian seaport managers. This research paper will conclude with a few policy insights for seaport managers in sustainable development decisions to discover areas for improvements in maritime sustainability and enhance the seaport competitiveness.

1. INTRODUCTION

Seaports are categorized as hard infrastructures for driving the economic growth of the nation [1]. Maritime shipping is one of the important modes of transport in the world, carrying over 80% of world trade by volume and 70% of its value [2]. Seaports coordinate the movement of cargo and services between the producers and consumers across the globe and act as transport centers in the intermodal logistics chain between waterways, railways, and airways [3]. In recent years, seaports across the globe have been facing challenges in developing sustainable aspects under the range of escalating environment-related awareness, compelling social responsibility along a mission for sustainable economic activities [4, 5]. The growth in seaport activities has also resulted in a destructive impact on the seaport environment and on society [4-8]. Thus, seaports have been forced to think beyond their conventional trade philosophy of growth in the economic dimension [7-9]. Seaports are required to develop economically in balance along with social development and continue being environmentally friendly [8-13].

With growing social, economic, and associated pressures from environmental aspects, seaport authorities across the globe are taking diverse measures to accomplish sustainability in seaport activities [11-13]. With the expansion of the concept of sustainability in various business sectors and the maritime supply chain, seaports across the globe are also sensing the responsibility of sustainability in their business model [4-15]. As a result, sustainability is getting consideration from seaport strategy framers, seaport & maritime body reports, and maritime researchers across the globe [11-15]. There have been various legislations and programs at national and global levels to make seaports clean and green. International Maritime Organisation's International Convention for Prevention of Pollution from Ships (MARPOL)73/78; GREEN PORTS Mission in India;IMO 2020 Global Sulphur Limit IMO 2019 [16-19]. In this connection, numerous research studies have been carried out in the maritime domain literature to determine the seaport's sustainable performance across the global seaports with specific dimensions of environment, society, and economy [4-15, 20-24].

The term sustainability comprises triple-baseline aspects of social, environmental, and economic dimensions and related practices [4-15, 20-24]. However,sustainable seaport development-related literature field has been concentrating primarily on the environmental-related dimensions [11, 20, 25]. Though, not much has been known about the crucial dimensions that form sustainable seaport development considering the holistic approach. Indian seaports have been performing as a critical logistics path for the export and import of various freight from India to many nations across the globe. At present, there are 12 major seaports and over 200 minor seaports in India spreading across a total of 7,516 kilometers [26]. In the Indian economy, seaports play a distinctive responsibility by handling over 90% of global cargo by volume and 80 percent by value [18, 20, 26, 27]. But sustainable seaport development is quietly gaining its rapidity in Indian seaports, as Indian seaports are lacking a common

structure for attaining sustainability along with its related dimensions considering sustainability performance in the maritime supply chain of seaports [20, 25, 26].

Hence, there is a need to address sustainability issues for assessing social, economic, and environmental-related dimensions for related aspects considering seaport supplier-carrier collaboration with seaport internal sustainable management for Indian seaports [5-8, 11-14, 24, 20, 25, 28]. This study primarily attempts to identify sustainable seaport dimensions, principal seaport performance indicators, and observed key seaport performance indicators to improve seaport sustainability. This study also assesses the importance of each dimension in the perspective of major seaports in India to propose a support structure towards future sustainable decisions in the maritime supply chain. The major impetus to conduct this research study on Indian major seaports is that seaports play a critical role in the national economic development. Secondly, Indian seaports are gaining a rapid pace in development as part of the sustainability program of MIV2030 under Sagarmala initiatives by the Government of India [18, 26, 27]. In the quest for sustainable seaport development, what other seaport sustainability dimensions and key performance indicators should be measured in the seaport's development structure, as well as their priority in seaport sustainability development.

This research paper is structured as follows: section two covers a theoretical framework with comprehensive systematic review of relevant literature on the concept of seaport sustainability considering a holistic conceptual framework approach and various research works carried out in the global seaports, identification of seaport sustainability factors and gaps for this research study. This is followed by the development of seaport sustainability research model development, discussion on research methodology which comprises of methods which includes: semi-structured confirmation interviews with seaport managers and maritime professionals in India and Fuzzy Analytical Hierarchy Process (FAHP) on seaport authorities are carried out. This section is followed by discussion and implications of results and findings of seaport sustainability assessment. Finally, this research paper concludes with a summary of research findings, limitations of the study and directions for further research interests of the authors.

2. LITERATURE REVIEW AND THEORETICAL FOUNDATION

2.1 Literature review on seaport sustainability studies

The global seaborne business and seaport development have led to major undesirable impacts on the environment which include an increase in noise level, reduction in air quality level, biodiversity loss, and increase in the level of water pollution, adverse impacts on public health and safety aspects [4-13, 15, 20, 22, 24, 25, 29-32]. With international conventions concerning environmental issues in maritime transportation being developed and enacted seaports are facing larger pressures to conform to regulatory and community requirements for leading towards effective sustainability [4-13, 15, 20, 22, 24, 25, 29-32]. Seaports have to take progressive action from a seaport sustainability perspective because it has become a principal concern when maritime transportation organizations are determining which seaport to use for cargo handling operations [4-13, 15, 20, 22, 24, 25, 29-32]. A seaport that operates at a high level of sustainability is more probable to draw support from the administration authorities, society, and impending maritime industry investors [4-13, 15, 20, 22, 24, 25, 29-32]. Seaports have thus, progressively more had to make extra investments to attain regulatory conformity and to expand their social accountability image [4-13, 15, 20, 22, 24, 25, 29-32].

The inclination of sustainable development in the maritime supply chain has been viewed in the seaport segment in recent years. It is noted through various research studies that seaport-related facilities improvement and seaport processes and activities have been playing a significant responsibility and exercising an influence on the expansion of seaports, shipping transportation, and maritime economies globally [4-13, 15, 20, 22, 24, 25, 29-32]. The development of seaports involves various stakeholders constituting multifaceted organizations considering economic, administrative, social, environmental-related dimensions and related aspects to comply with demands of business-related performance with sustainable development-related aspects [4-13, 15, 20, 22, 24, 25, 29-31]. Considering the above situation and the increasing importance of seaport sustainability, the International Association of Ports and Harbors set up a World Port Sustainability Program to deal with the ecological and societal concerns by integrating the mechanism of seaport sustainability and exaggerated sustainability-related efforts of seaports [16].While social and environmental aspects issues in the seaports around the globe are not new, it is noteworthy that the principal maritime-related organization of the world is officially selecting and announcing the winners as recognition of seaport sustainable related development efforts.This has helped global seaports to line up with international sustainability standards by executing vision of United Nations Sustainable Development Goals in maritime context [17].

Although the theme of seaport sustainability development and its related aspects has received emergent attention from global maritime practitioners and researchers in recent times, only a limited amount of seaport functions related literature remains inadequate in this domain [4-13, 15, 20, 22, 24, 25, 28-30]. In existing literature regarding sustainable seaport development, only a few maritime researchers have discussed and covered the comprehensive aspects under the topic of seaport sustainable development covering related sustainability dimensions [4-13, 15, 22, 24, 28, 30]. While the majority of the research studies on seaport sustainability development only dealt with the examining of seaport environment factor and related issues along with its indicators [4-14, 20-25, 28-31, 33-47]. In addition, maritime field literature, primarily focused on seaport environmental-related approaches involving concepts green seaports, while a few other research studies considered triple-bottom-line dimensions and related aspects [4-14, 20-25, 28-31, 33-36, 38-47]. Many research studies also indicated that the majority of the seaport sustainability research studies were literature emphasized and considered in the aspects of port area air quality, port-related green gas emissions, port area water condition, port energy consumption, noise at the port area, port carbon footprint, and port waste management mechanism considering environmental dimension; port stakeholder involvement, port competition, port resource utilization, port financial state, and port relationships and port logistics-related aspects and port traffic & financial forecast methods considering port economic dimension; port employment

generation, port security, and safety, port corporate social responsibility, port community relationships, port transparency in social factors [4-14, 20-25, 28-31, 33-36, 38-47].

Few research studies determined fragmented sustainability based dimnesion research with many number of research publications over the time span, till recently has been progressively rising with major concern in the area still being seaport sustainability performance and its related indicators evaluation. It was also found that much of the research work in conceptualizing a sustainable framework for seaports captures information from the particular geography of China, South Korea, Singapore,Vietnam, Taiwan, Egypt, UK & EU region ports with containers as major handling cargo [4-8, 10-13]. Many researchers have also tried to examine seaport sustainability and its related aspects with a case study of particular geographical related seaports but only a few seaport sustainable development dimensions and related performance indicators have been validated by the population restricted to one or two seaports in a geographical scope [9-11, 13-15, 22, 24, 48].

Also, Indian seaports are accountable for passing through 70% of the nation's traffic operations by value [18, 20, 25-27]. Sustainable seaport development in Indian seaports is still gaining its pace because the majority of seaports in India lack widespread support for achieving sustainability in seaports covering all sustainability dimensions and its practices from a sustainability management perspective [20, 26]. To the best of knowledge, no research or academic study is accessible to strengthen the structure for sustainable seaport development by considering the maritime supply chain from the Indian seaport context. While numerous maritime researchers in the seaport domain recognize the requirement for measuring sustainable related practices by also considering seaport and related maritime supply-chain, there are relatively few empirical studies that discussed and reviewed which includes port suppliers, port customers, and other port-related stakeholder opinions which forms a critical view regarding comprehensive seaport sustainability performance implementation [20, 26].

Hence, there is a requirement of the system with the efficient performance of sustainability-related dimensions and its related practices in seaports by considering sustainable management aspects internally within seaport environment and externally in partnership with stakeholder members. Addressing such research gaps, present research intends to set up & confirm the abstract model of sustainable seaport development covering sustainability maritime supply chain and its related aspects for Indian major seaports.

2.2 Systematic literature review

A sustainable seaport aims to progress the equilibrium of economic efficiency along with environmental and societal dimensions and related sustainable practices in the seaport. To understand the topic of the "seaport sustainability" concept, a literary database was searched. Elsevier's Scopus is one of the established databases for peer-reviewed collections of journals and is considered to be an excellent alternative to other databases like the Web of science due to its ease of use [8, 11, 35]. Thus, using the Scopus database article list and their details on seaport sustainability are extracted and analyzed. The systematic steps adopted to carry out the literature search and the review process is discussed as follows:

Step 1: Use of keywords: The following keyword protocol has been used to perform the literature search, title key ("seaport sustainability" OR "sustainable seaports"), which was limited to document type of articles and source type journal. The exclusion measure included conference articles, research dissertations, thesis reports, book related chapters, and other grey literatures in only in English language is selected. Also, sustainability aspects in seaports and maritime domain have been progressively highlighted in various research studies since 1987 and in this the research study, interval period considered from year 1987 till December 2021. The above keyword search was used on 11th January 2021 and yielded a list of 96 journal articles published in the area of seaport sustainability.

Step 2: Further document search was carried out on search engines of individual journal publisher's websites of repute, like Science Direct, Taylor and Francis, Springer, SAGE, Emerald, Wiley, and Inderscience. The keywords used here were "seaport sustainability" OR "sustainable ports". The manual search with these keywords was carried out on 7th January 2022 for which article lists were obtained (Table 1).

Table 1. Articles extracted through key journal publisher's website search engine

Journal Publisher	No. of articles on seaport sustainability OR sustainable seaports
Elsevier	96
Emerald	58
Inderscience	31
Sage	11
Springer	79
Taylor & Francis	37
Wiley	26

Step 3: All article lists from Step1&2were listed and consolidated to eliminate the recurring article titles, final list of the articles is obtained, which had 338 journal articles.

Step 4: From these 304 articles, only relevant documents on the focus area of seaport sustainability assessment with a comprehensive supply chain perspective are shortlisted for further review. A list of 137 relevant articles to the topic was obtained, which was reviewed to identify the research gaps.

3. METHODOLOGY

Seaports play a very vital role in the integration of maritime supply chains along with triple bottom line dimensions for sustainable development-related activities. Further scalability with seaport's internal management and customer/supplier collaboration with port stakeholders through various stakeholder management theories [11]. It is therefore predicted that sustainable seaport enhancement activities are a combined aspect of managing the triple bottom line approach for seaport operations aimed at balancing the interests of the seaport and its related stakeholders aspects. The main motivation of this research is to identify the theoretical and practical aspects of seaport sustainability dimensions, principal performance indicators, and practices using the Indian major seaport context. Since there is scarce in research regarding dimensions, performance indicators, and seaport important practices that shape sustainable seaport development. This research adopts four sustainability dimnesions, fourteen principal performance indicators, and one hundred fifteen sustainable port

development practices derived from a comprehensive literature review.

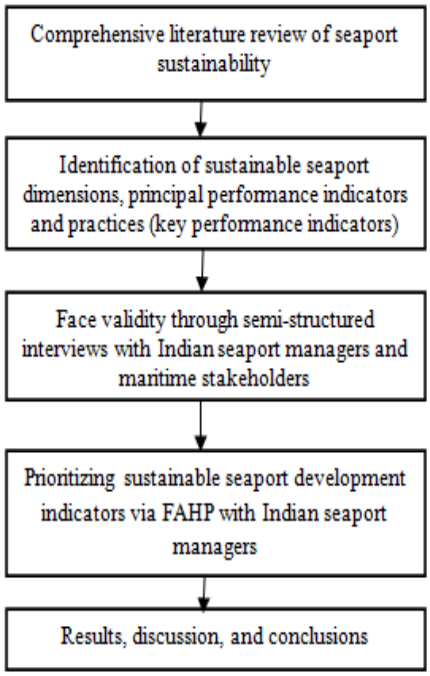

Figure 1. Sequence steps of methods used in this research

Figure 1 illustrates sequence steps of various methods used in this research study [11]. This research study adopts multi-phased mixed methods, which combinies semi-structured interviews for face validation and Fuzzy Analytical Hierarchy Process (FAHP) for prioritizing sustainable seaport development factors. First, a semi-structured interview questionnaire was designed on a comprehensive review of literature (Table 1). Based on previous literature studies of various global seaports, these key performance indicators or practices were then categorized into four dimensional aspects, considering 12 major seaports in India for which interview questions were distributed. Findings from this research stage would present face validity towards sustainable seaport development indicators in the Indian seaport context. Once this step is completed, FAHP study is conducted to reveal its priority.

3.1 Port Sustainability research model

The proposed holistic conceptual research framework model for Indian major seaports is illustrated in Figure 2.

3.2 Port sustainability dimensional approach

Based on literature review, sustainability port key performance indicators are categorized into four main categories that comprise of environmental performance dimension with four seaport performance indicators and forty-four key port performance indicators as illustrated in Table 2; social performance dimension with three seaport performance indicators and, twenty-four key port performance indicators as illustrated in Table 3; economic performance dimension with four seaport performance indicators and twenty-seven key port performance indicators as illustrated in Table 4 and sustainability performance indicators with three seaport performance indicators and twenty key port performance indicators in Table 5.

Since there has been limited research on the dimensions which outline sustainable seaport development, this research study adopted the 115 sustainable key performance seaport development indicators or seaport sustainable related practices (Table 6), which were derived from a wide range of seaport sustainability literature studies across the global seaports and seaport sustainability-related practices at seaports which were empirically validated using in-depth interviews [11]. Hence, there is a necessity to validate the key performance port-related indicators or seaport practices identified through various literature studies and to prioritize the seaport sustainability dimensions considering Indian seaports context by employing further precise methods to improve their consistency and validity. Therefore, in this research study semi-structured interviews were initially conducted to confirm various sustainable seaport development indicators from seaport manager's and maritime expert's perspectives from Indian seaports.

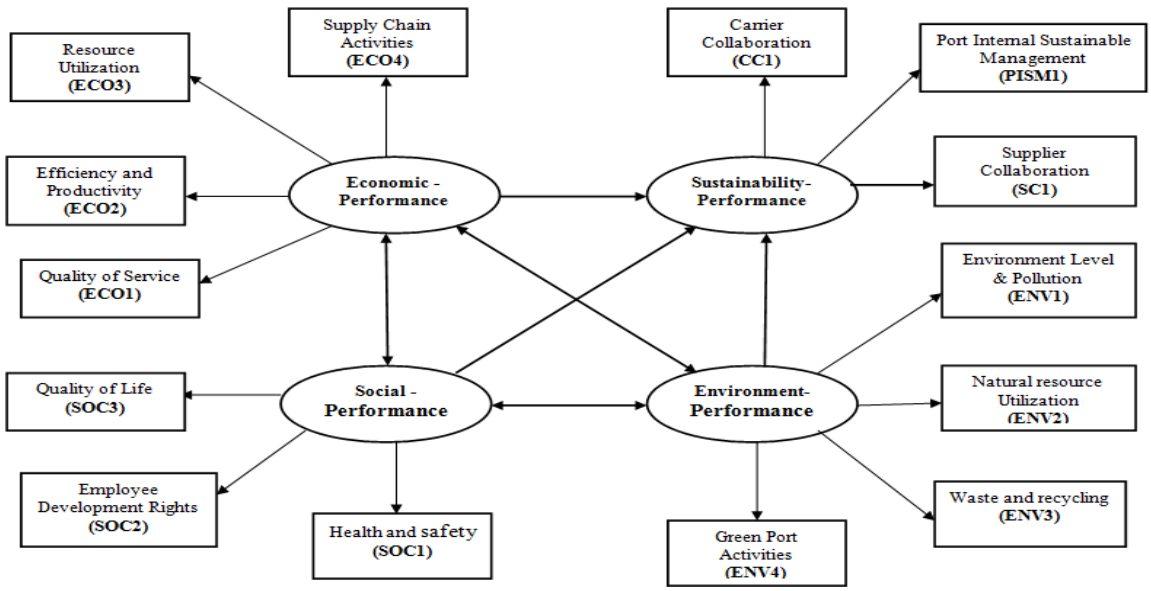

Figure 2. Seaport sustainability research model

Table 2. Environment- performance dimension PPI's and observed KPI's with literature

Port Dimension: Environmental Performance (Env-Performance)	Literature (References)
Principal PPI: Environmental level & pollution (ELP) Observed Port KPI's: ELP 1. Air quality ELP 2. Greenhouse gas emission level ELP 3. Carbon emission level ELP 4. Exhaust of gases & particles ELP 5. Emission inventory tracking ELP 6. Smoke level ELP 7. Noise Level ELP 8. Odour pollution ELP 9. Water quality level ELP 10. Soil Contamination ELP 11. Coastal erosion ELP 12. Oil pollution ELP 13. Dredging	[4-16, 20-25, 28-32, 34-39, 42-47]
Principal PPI: Natural resource utilization (NRU) Observed Port KPI's: NRU 1. Water Consumption Rate NRU 2. Fuel Consumption Rate NRU 3. Energy Consumption Rate NRU 4. Energy conservation NRU 5. Renewable energy usage NRU 6. Alternative fuel facilities NRU 7. Shore power facility support NRU 8. Land usage NRU 9. Resource conservation NRU 10. Aquatic environment	
Principal PPI: Waste and recycling (WR) Observed Port KPI's: WR 1. Ballast water handling WR 2. Spill prevention WR 3. Sewage disposal mechanism WR 4. Handling of solid/liquid wastes WR 5. Handling of hazardous cargo WR 6. Garbage disposal management	
Principal PPI: Green Port activities (GPA) Observed Port KPI's: GPA 1. Slope Reception facility GPA 2. Climate change adaptation strategy GPA 3. Sustainability purchasing GPA 4. Re- usage mechanism support GPA 5. Modern equipment & automation usage GPA 6. Paper Usage level GPA 7. Support sustainable mobility GPA 8. Green program Support incentives GPA 9. Green Belt level GPA 10. Green Transport & warehouse manage GPA 11. Vehicle utilization & parking system GPA 12. Environment objective & targets GPA 13. Environment committee & professional involvement GPA 14. Environment legislation & code of practices GPA 15. Port Cleanliness	

Interviewees were asked to indicate whether the seaports in India should incorporate the proposed seaport sustainable development indicators or practices, which were reflected in all four dimensions, fourteen principal performance indicators, and 115 key performance indicators and their related aspects. Their responses were categorized into value 0: indicating No, value 1 indicating Yes, and a symbol Δ indicating the status of Not sure for various Indian seaport practices. The email mechanism was used to distribute interview questionnaires to 12 major seaports in India. In total of 87 responses were from Indian seaport managers and maritime professionals.

Table 3. Social- performance dimension PPI's and observed KPI's with literature

Port Dimension: Social Performance (Soc-Performance)	Literature (References)
Principal PPI: Health and Safety (HS) Observed Port KPI's: HS 1. Safety Level HS 2. Traffic accidents likelihood HS 3. Fatality accidents likelihood HS 4. Security Access control mechanism HS 5. Adequate monitoring & threat awareness HS 6. Health care service quality HS 7. Periodic drillsin Port HS8: Emergency Disaster Management Plan	[4-16, 20-25, 28-33, 34-37, 39, 42, 45-47]
Principal PPI: Employment development rights (ED) Observed Port KPI's: ED 1. Employees benefits & job security ED 2. Equal opportunities to employees ED 3. Employee Rights	
Principal PPI: Quality of life (QL) Observed Port KPI's: QL 1. Proximity/accessibility to City QL 2. Support local identity & culture QL 3. Community relationship & development QL 4. Employment & training local community QL 5. Local community communication QL 6. Consult concerned interest groups QL 7. Stakeholder Commitment QL 8. Support to innovation initiatives QL 9. Congestion solving initiatives QL 10. Administration & governance issues QL 11. Inter organization collaboration QL 12. Right to information service QL 13. CSR support	

Table 4. Economic- performance dimension PPI's and observed KPI's with literature

Port Dimension: Economic Performance (Eco-Performance)	Literature (References)
Principal PPI: Quality of service (QS) Observed Port KPI's: QS 1. Quality Management systems QS 2. Customer Satisfaction Rate QS 3. Collaboration & ease of business	[4-16, 20-25, 28-33, 34-37, 39, 42, 45-47]
Principal PPI: Efficiency and Productivity (EP) Observed Port KPI's: EP 1. Traffic volume level EP 2. Financial-performance (Income/Profit) EP 3. Port operational efficiency EP 4. Port throughput EP 5. Asset productivity EP 6. Land Price EP 7. Cost efficiency strategy EP 8. Management of business EP 9. Trade facilitation strategy EP 10. Tourism management strategy EP 11. Investment on climate change adoption activities EP 12. Investment in innovation strategy EP 13. Operational Performance evaluation	
Principal PPI: Utilization of resources (UR) Observed Port KPI's: UR 1. Employee wage & benefits UR 2. Infrastructure-development support	

UR 3. Utilization of land & space UR 4. Information system usage	
Principal PPI: Supply chain activities (SCA) Observed Port KPI's: SCA 1. Information sharing SCA 2. Intermodal transport systems SCA 3. Information Communication Technology services SCA 4. Capacity to handle diverse cargo SCA 5. Cargo damage incidence SCA 6. Delay incidence SCA 7. Efficiency of logistic operations	

Table 5. Sustainability- performance dimension PPI's and observed KPI's with literature

Port Dimension: Sustainable Performance (Sust-Performance)	**Literature (References)**
Principal PPI:Supplier Collaboration (SC) Observed Port KPI's: SC 1. Acquire ISO 14001 or equivalent certification SC 2. Sustainable development programs SCA 3. Evaluating port carrier's operational performance SCA 4. sustainable development specs SCA 5. Sustainable development evaluation of Carriers SCA6.Seaport assistance to set sustainable related development policy SCA 7. Setting of sustainable development indicators with seaport SCA 8. Work with seaport to ease impacts on port areas	[4-12, 14, 21, 22, 28-31, 36, 46, 47]
Principal PPI: Port Internal Sustainable Management (PIP) Observed Port KPI's: PIP 1. Sustainability Participation PIP 2. Sustainability Training PIP 3. Sustainability Practices PIP 4. Sustainable Policy	
Principal PPI: Carrier/Customer Collaboration (CR) Observed Port KPI's: CR 1. Acquire ISO 14001 or equivalent certification CR 2. Implement sustainable development programs CR 3. Evaluating port carrier's operational performance CR 4. Written sustainable development specs CR 5. Evaluation of Carriers CR 6. Assistance for sustainable development policy CR 7. Setting indicators with port for sustainable development CR 8. Work with seaport to reduce impacts in port areas	

Table 6. Attitude towards sustainable seaport development practices in Indian major seaport context (% of responses)

Sustainability Seaport Practices/Key Performance Indicators in Ports	**1-Yes**	**0-No**	**Δ-Not sure**
ELP 1. Air quality level	97	3	0
ELP 2. Greenhouse gas emission level	98	2	0
ELP 3. Carbon emission level	96	2	2
ELP 4. Exhaust of gases & particles	91	4	5
ELP 5. Emission inventory tracking	93	1	6
ELP 6. Smoke level	99	0	1
ELP 7. Noise Level	94	4	2
ELP 8. Odour pollution	91	4	5
ELP 9. Water quality level	98	0	2
ELP 10. Level of Soil Contamination	94	0	6
ELP 11. Coastal erosion	97	0	3
ELP 12. Oil pollution	98	2	0
ELP 13. Dredging activitty	91	3	6
NRU 1.Water Consumption Rate	98	0	2
NRU 2. Fuel Consumption Rate	99	0	1
NRU 3. Energy Consumption Rate	98	0	2
NRU 4. Energy conservation	99	0	1
NRU 5. Renewable energy usage	99	0	1
NRU 6. Alternative fuel facilities	98	0	2
NRU 7. Shore power facility support	97	0	3
NRU 8. Landscape usage	95	0	5
NRU 9. Resource conservation	97	1	2
NRU 10. Aquatic environment	99	0	1
WR 1. Ballast water handling	90	0	10
WR 2. Spill prevention	98	0	2
WR 3. Sewage disposal mechanism	99	0	1
WR 4. Handling of solid/liquid wastes	99	0	1
WR 5. Handling of hazardous cargo	98	0	2
WR 6. Garbage disposal management	99	0	1
GPA 1. Slope Reception facility	97	1	2
GPA 2. Climate change adaptation	99	0	1
GPA 3. Sustainability purchasing	98	0	2
GPA 4. Re- usage mechanism support	90	4	6
GPA 5. Modern equipment & automation usage	96	2	2
GPA 6. Paper Usage level	92	3	5
GPA 7. Support sustainable mobility	96	0	4
GPA 8. Green program Support	99	0	1
GPA 9. Green Belt level	99	0	1
GPA 10. Green Transport & warehouse management	98	0	2
GPA 11. Vehicle utilization & parking mechanism	94	2	4
GPA 12. Environment objective & targets	99	0	1
GPA13.Environment committee & professional involvement	99	0	1
GPA 14. Environment legislation & code of practices	98	0	2
GPA 15. Port Cleanliness	99	0	1
HS 1. Safety Level	99	0	1
HS 2. Traffic accidents likelihood	98	0	2
HS 3. Fatality accidents likelihood	97	1	2
HS 4. Security Access control mechanism	94	0	6
HS 5. Adequate monitoring & threat awareness	93	2	5
HS 6. Health care service quality	99	0	1
HS 7. Periodic Accident drills	98	0	2
HS8. Emergency Management Plan	99	0	1
ED 1. Employees benefits & job security	99	0	1
ED 2. Equal opportunities to employees	99	0	1
ED 3. Employee Rights	98	0	2
QL 1. Proximity & accessibility City	90	4	6
QL 2. Support local identity & culture	85	10	5
QL 3. Community relationship	96	1	3
QL 4. Employment & training local community	99	0	1
QL 5. Local community communication & support	99	0	1
QL 6. Consult concerned groups	90	3	7
QL 7. Stakeholder Commitment	99	0	1
QL 8. Support to innovation	90	6	4
QL 9. Congestion solving initiatives	85	5	10
QL 10. Administration & governance issues	90	4	6
QL 11. Inter organization collaboration	88	2	10
QL 12. Right to information service	86	3	11

QL 13. CSR support	96	2	2
QS 1. Quality Management systems	99	0	1
QS 2. Customer Satisfaction Rate	99	0	1
QS 3. Work collaboration & ease of doing business	98	0	2
EP 1. Traffic volume level	99	0	1
EP2.Financial-performance (Income/Profit)	98	0	2
EP 3. Port operational efficiency	94	2	4
EP 4. Port throughput	95	3	2
EP 5. Asset productivity	96	0	4
EP 6. Land Price	99	0	1
EP 7. Cost efficiency strategy	98	0	2
EP 8. Management of business	99	0	1
EP 9. Trade facilitation strategy	98	0	2
EP 10. Tourism management strategy	96	2	2
EP 11. Investment on climate change	96	2	2
EP12.Investment in innovation strategy	94	3	3
EP13. Operational Performance evaluation	92	2	6
UR 1. Employee wage & benefits	99	0	1
UR2.Infrastructure-development support	90	4	6
UR 3. Utilization of land & space	87	4	9
UR 4. Information system usage	98	1	1
SCA 1. Information sharing	99	0	1
SCA 2. Intermodal transport systems	98	2	0
SCA 3. ICT services	94	2	4
SCA 4. Capacity-handle diverse cargo	98	0	2
SCA 5. Cargo damage incidence	90	2	8
SCA 6. Delay incidence	90	2	8
SCA7.Efficiency of logistic operations	89	4	7
SC1.Acquire ISO 14001 or equivalent certification	99	0	1
SC2.Sustainable development programs	97	1	2
SCA3.Evaluating port carrier's operational performance	98	0	2
SCA4.Written sustainable development specs	97	0	3
SCA 5. Sustainable development evaluation of Carriers	98	0	2
SCA6.Port assistance to set sustainable development policy	98	0	2
SCA 7. Setting port sustainable development indicators	97	0	3
SCA 8. Work to reduce impacts in port areas	99	0	1
PIP 1. Sustainability Participation	89	7	4
PIP 2. Sustainability Training	87	3	10
PIP 3. Sustainability Practices	89	2	9
PIP 4. Sustainable Policy	87	4	9
CR 1. Acquire ISO 14001 or equivalent certification	82	5	13
CR 2. Implement sustainable development programs	84	2	14
CR 3. Evaluating port carrier's operational performance	90	3	7
CR 4. Written sustainable development specs	86	2	12
CR 5. Evaluation of Carriers	83	4	13
CR 6. Assistance to set sustainable development policy	89	2	9
CR 7. Setting port sustainable development indicators	84	3	13
CR 8. Work to reduce impacts on port areas	88	2	10

3.3 Fuzzy Analytical Hierarchy Process (FAHP) analysis

The fuzzy AHP technique handles linguistic variables by confining an expert's indecisive and imprecise judgment [11]. Trapezoidal fuzzy numbers have been used in this research study to compute weights. This method is based on confidence index 'α' with an interval mean procedure and fuzzy interval arithmetic with triangular fuzzy numbers to set up weights for assessing various elements. FAHP procedure is highlighted in Appendix A. In this phase, a total of 23 Indian seaport top-level authorities participated to evaluate the FAHP research structure.

4. RESULTS AND FINDINGS

The present research study conducted semi-structured interviews via email process to validate sustainable seaport development practices from the perspective of maritime practitioners and seaport managers in an Indian major seaport context. This method was used to distribute the interview protocol to 12 major seaports in India and maritime domain experts in India with total of 87 responses were received. Their working experience ranged from 5 to 10 years (31.34%), 10 to 15 years (14.93), 16 to 20 years (53.73%). Interview respondents were asked to specify whether a seaport in India should include the proposed seaport sustainable development practices for related dimensions and its related port principal performance aspects. Their responses were coded with values as 0 indicating No, value 1 indicating Yes, and value Δ indicating not sure whether seaport practices are required under the view of seaport sustainability.The majority of the seaport managers approved to include all the proposed sustainable related practices in all the four sustainable development dimensions and their related aspects framework. The various dimensions, port principal performance indicators, and seaport practices of sustainable seaport development were validated through Phase-1semi structured interviews as shown in Table 6.

The results of FAHP analysis from Indian seaport top level authorities are highlighted in Table 7. The consistency ratio of the pair-wise comparison matrix is 0.018 which is lesser than 0.1, meaning the pair-wise assessment is adequate and constant. Table 7 values in this research indicate that the economic performance dimension was considered the most important aspect with the weight of 0.3198 followed by the sustainability performance dimension and environmental performance dimension with the respective weights of 0.3005 and 0.1963. Meanwhile, social performance was measured as the least imperative among sustainable seaport development factors with a weight of 0.1835. This research finding replicate the survey results found in the validation step of semi-structured interviews of seaport managers and maritime professionals in the Indian maritime perspective.

Specifically, the Indian seaport's economic-related dimensions along with seaport sustainability dimensions, involves active collaboration with seaport partners for improvement in seaport trading, facility management, port-stakeholder business-related system development, regular interactive meetings, as stakeholder collaboration was perceived as the generally significant dimension for sustainable seaport development. Table 7 indicates that social programs activities for seaports in India were considered least important by seaport authorities although their seaports have already implemented a variety of social programs to facilitate community development in port areas.

Table 8 illustrates the typology of the stakeholder decision framework regarding sustainable seaport development, considering four dimensions considering various practices for seaport sustainability [11, 24, 28, 48]. Seaports also should

consider primary stakeholders and secondary stakeholders with the importance of practices to the seaport stakeholders and actions to be taken by the seaports with the status- P: Proceed, S: Suspend, N: Negotiate. Based on the comprehensive sustainable seaport development structure and the above research results, this study also represents seaport stakeholder's decision structure for sustainable seaport development in Indian seaports are highlighted in Table 7. Using this structure as benchmarking option to formulate decisions and execute particular sustainable seaport development dimensions and related port practices. Seaport managers need to construct the relationship matrix involving the seaport and various related stakeholders of the seaport. If a sustainable seaport dimension in the four dimensions sustainable seaport development structure is considered significant by seaport authorities and stakeholders, the seaport has to proceed with the formulation and execution of sustainability practices.

Table 7. Results of FAHP analysis (Indian port managers)

Dimension of Seaport sustainability	Weights	BNP1	STD BNP1	Rank
Environmental performance	(0.1355,0.195, 0.2854)	0.2053	0.1963	**3**
Social performance	(0.1245,0.182, 0.2691)	0.1919	0.1835	**4**
Economic performance	(0.222,0.321, 0.4597)	0.3705	0.3198	**1**
Sustainability Performance	(0.2091,0.301, 0.4329)	0.3143	0.3005	**2**

$\lambda max = 8.172$;
CR = 0.018;
CI = 0.025; RI = 1.4
BNP1 (Best non-fuzzy performance) = $[(U - L) + (M - L)]/3 + L$.;
STD BNP1: Standardised BNP.

Table 8. Typology of stakeholder decision framework for seaport sustainable development

Seaport stakeholder decision framework for sustainable seaport development Is the practice important to the seaport sustainability?		Is the practice vital to the seaport stakeholder? (P: Proceed, S: Suspend, N:Negotiate)			
		Seaport Primary Stakeholders		Seaport Secondary stakeholders	
		Yes	No	Yes	No
Environmental performance	Yes	P	N	P	N
	No	P	S	N	S
Social performance	Yes	P	N	P	N
	No	P	S	N	S
Economic performance	Yes	P	N	P	N
	No	P	S	N	S
Sustainability performance	Yes	P	N	P	N
	No	P	S	N	S

Vice versa, if a dimension measured is not vital by seaport authorities or seaport-related stakeholders, formulation and execution of sustainability practices have to be suspended. If only the seaport authorities contemplate that the seaport dimensions are vital, while the seaport stakeholders do not consider the same, then the seaport authorities will need to engage in negotiation and consultation activities with related seaport stakeholders towards formulation and execution of sustainability practices. If the seaport authorities do not consider a sustainability dimension to be significant as the seaport stakeholders do, then the seaport authorities need to continue considering the prominent association that the seaport stakeholders have with the seaport. However, if a sustainability dimension is not of importance for both the seaport authorities and seaport primary stakeholders and if secondary seaport stakeholders identify else, then the seaport managers need to negotiate and deliberate on consideration whether particular sustainability-related dimension for seaport would have a medium-range or long-range constructive impacts on the seaport sustainability practices or for the short-range duration.

5. DISCUSSIONS AND IMPLICATIONS

5.1 Discussions

The idea of seaport sustainability has been commonly introduced to the area of the maritime and seaport industry from a financial and environmental viewpoint. Despite those advancements, the question remains of how the seaport can achieve sustainability as adopted in this research study.It was discovered through various literature review studies and confirmation of all seaport sustainability practices through an evaluation with 87 participants in India through semi-structured interviews, and a total of 23 Indian major seaport top level authorities participated in evaluating the FAHP research. However, with the COVID-19 epidemic, the maritime policy-making organizations and seaports emphasize the evolution to an eco-friendly and inclusive economy considering social aspects and complete maritime supply chain stakeholders. This research study's framework can consequently support seaport managers and other maritime policymakers to manage this paradigm shift. For this seaport sustainability assessment to be carried out properly, attempts should be made to change and improve the seaport stakeholder's insights and understanding towards sustainable seaport development aspects.

5.2 Theoretical & policy contributions

First, the sustainable seaport development framework in this research study proposes literature study validation in the case of major Indian seaports. This study conceptualizes a system for a seaport to widen into a holistic sustainably seaport based on improvement structure. Using this structure as a focal point, the assessment to formulate and execute specific sustainable seaport development practices which seaport manager needs to consider from various seaport related stakeholder's perspectives [26]. From the policy viewpoint, the findings of this research and the related recommendation decision framework of this research study offer valuable assistance to maritime researchers in broader aspects of sustainability in the Indian seaport context. Based on this research structure developed in this study; consideration of an all-inclusive and organized decision support system is possible towards the development of sustainable seaports. The confirmed sustainable seaport development dimensions and key port performance indicators provide guidelines for seaport authorities and seaport stakeholders on how their seaports should be developed for sustainability.

Since, seaport sustainability-related dimensions are

prioritized with significance by seaport managers, this research will assist in the areas of maritime research which should be decisive for the development of seaport sustainably. This research study contributes equally to existing literature and also to practices involved in various seaport organizations towards extending sustainably aspects along with the involvement of various seaport stakeholders. Further from the primary findings of this research study, a sustainable development seaport needs to formulate and execute seaport sustainable related activities involving stakeholders of the seaports. Seaport managers also need to decide on how to balance various sustainability-related practices and activities of seaports, considering the complex network of seaport-related stakeholders and their views on sustainability aspects. In the present scenario in the seaport sector, investments in social dimension-related aspects overhead in investment and infrastructure are extremely been highlighted in priority considering sustainability. To construct efficient & effective infrastructure development for a sustainable seaport, it is significant to assess the sustainable seaport development dimensions and indicators involving structural and functional processes constantly.

Considering the primary seaport dimensions and sustainability-related practices that have surfaced from the research results, policies that can sustain the abilities of the global major seaport organizations can be suggested. The results of this research study can further assist in developing medium and long-term sustainable strategies for each seaport organization by dynamically identifying responsibility to develop and progress on the seaport environment aspects and to contribute to the local society. The results of this research study will also support in making excellent macro decisions by seaport authorities to make the best use of the constructive effects of social and environmental values and also economic aspects of maritime supply chain collaboration in the present development plan of global seaports. Seaport authorities can determine the impact on the local community caused by seaports to know how many society-related and local-community-related changes have transpired due to attribution of seaport-related activities, to become general practices for all the seaports. Seaports must also put more effort with the aim at developing a sustainability framework and guidelines for seaport stakeholders through preparing a business continuity plan, logistics policy, development of the consolidated seaport stakeholder institutional framework, and disaster management plan for the emergency circumstances arising in the seaport perspective [26]. Thus, the research assessment structure will be constructive for macro assessment basis to for the balanced vision of seaports responsibilities in local society and seaport related stakeholders.

6. CONCLUSIONS

This research study primarily conceptualizes a sustainable seaport development structure for Indian major seaports by viewing seaport sustainable improvement and stakeholder organization theories to involve seaport sustainability-related indicators which have been adopted from various literature studies across global seaports. The structure in this research study is empirically confirmed in the perspective of Indian major seaports and the precedence rankings of sustainable development dimensions. This research study further involves a comprehensive advancement that involves all dimensions and also takes into account all key seaport-related stakeholders considering sustainable seaport development aspects. Seaport managers and Indian maritime domain experts in this research study through semi-structured interviews have confirmed that the majority of the indicators or seaport practices in the projected research model should be incorporated towards the development of sustainable seaport development.

Further, FAHP analysis indicated that seaport top-level authorities in India perceived that seaport's economic dimension is the most important dimension for a seaport sustainability development. Seaport social performance and seaport environmental performance was professed to be the least significant dimensions by Indian seaport managers and maritime experts respectively. Nevertheless, diverse limitations exist in the present research study. Particularly, the research study responses were low and have been taken online through the online email technique. This limitation was mainly due to an inadequate time frame and the impacts caused due to the COVID-19 scenario across the Indian seaports. However, this research study could be a way for advanced research in systematic comprehensive assessment sustainability for seaports to inform about sustainable related improvement strategies for the future seaport expansion and development.

This research study does not consider the sustainability assessment of private seaports or state minor seaports in India. Further, the findings of this research study can be compared with other region seaport's sustainability performance assessment framework. Future research studies may be carried out by measuring seaport sustainability performance using real-time value-based sustainability initiatives data of seaports across the globe.

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APPENDIX

Appendix A: The FAHP Procedure

FAHP procedure for this research work is adopted from literature reference [11].

1. Establishing fuzzy number

A fuzzy number $\tilde{A}$ on R to be a triangular fuzzy numbers (TFN) if its membership functions $\mu_{\tilde{a}}(x)$: R → [0, 1] is equal to following Eq. (1):

$$\mu_{\tilde{a}}(x) = \begin{cases} (x - l) / (m - l), & l \le x \le m \\ (u - x) / (u - m), & m \le x \le u \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

From Eq. (1), l and u mean the lower and upper bounds of the fuzzy number $\tilde{A}$, and m is the model value for $\tilde{A}$ (as Figure 2). The TFN can be denoted by $\tilde{A}$ = (l, m, u). The operational laws of TFN $\tilde{A}1$ = (l1, m1, u1) and TFN $\tilde{A}2$ = (l2, m2, u2) can be expressed in the following Eqns. (2) – (6).

Addition of the fuzzy number $\oplus$

$$\tilde{A}1 \oplus \tilde{A}2 = (l1, m1, u1) \oplus (l2, m2, u2)$$
$$\tilde{A}1 \oplus \tilde{A}2 = (l1 + l2, m1 + m2, u1 + u2) \quad (2)$$

Multiplication of the fuzzy number $\otimes$

$$\tilde{A}1 \otimes \tilde{A}2 = (l1, m1, u1) \otimes (l2, m2, u2)$$
$$\tilde{A}1 \oplus \tilde{A}2 = (l1l2, m1m2, u1u2) \text{ for } l1, l2 > 0;\ m1, m2 > 0;\ u1, u2 > 0 \quad (3)$$

Subtraction of the fuzzy number Θ

$$\tilde{A}1 \Theta \tilde{A}2 = (l1, m1, u1) \Theta (l2, m2, u2)$$
$$\tilde{A}1 \Theta \tilde{A}2 = (l1 - l2, m1 - m2, u1 - u2) \quad (4)$$

Multiplication of the fuzzy number $\oslash$

$$\tilde{A}1 \oslash \tilde{A}2 = (l1, m1, u1) \oslash (l2, m2, u2)$$
$$\tilde{A}1 \oplus \tilde{A} = (l1 / l2, m1 / m2, u1 / u2) \text{ for } l1, l2 > 0;\ m1, m2 > 0;\ u1, u2 > 0 \quad (5)$$

Reciprocal of the fuzzy number

$$\tilde{A}\text{-}1 = (l1, m1, u1)\ \text{-}1 = (1 / u1, 1 / m1, 1 / l1) \text{ for } l1, l2 > 0;\ m1, m2 > 0;\ u1, u2 > 0 \quad (6)$$

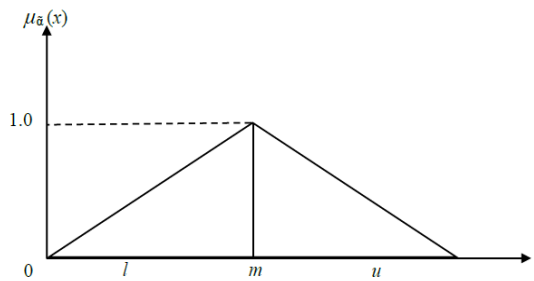

Figure F1. The membership functions of the triangular fuzzy number [13]

2. Determining the linguistic number

The concept of linguistic variables is very practical in handling with ill-defined or complex situations reasonably described in conventional quantitative expressions. A linguistic variable is a value that can be artificial or natural language in forms of sentences or words. Table 3 shows the equivalent fuzzy numbers and linguistic comparison terms considered in this study.

Table T1. Fuzzy comparison measures

Fuzzy number	Linguistic	Scale of fuzzy number
9	Perfect	(8, 9, 10)
8	Absolute	(7, 8, 9)
7	Very good	(6, 7, 8)
6	Fairly good	(5, 6, 7)
5	Good	(4, 5, 6)
4	Preferable	(3, 4, 5)
3	Not bad	(2, 3, 4)
2	Weak advantage	(1, 2, 3)
1	Equal	(1, 1, 1)

3. FAHP procedure

Step 1: Construct pairwise comparison matrices among all the indicators in the dimensions of the hierarchy system. Assign linguistic terms to the pairwise comparisons by asking which is more important of each two dimensions, as following matrix $\tilde{\mathbf{A}}$ shown in Eq. (7).

$$\tilde{\mathbf{A}} = \begin{bmatrix} 1 & \tilde{\alpha}12 & \dots & \tilde{\alpha}1n \\ \tilde{\alpha}21 & 1 & \dots & \tilde{\alpha}2n \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{\alpha}n1 & \tilde{\alpha}n2 & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{\alpha}12 & \dots & \dots & \tilde{\alpha}1n \\ 1/\tilde{\alpha}12 & 1 & \dots & & \tilde{\alpha}2n \\ \vdots & \vdots & \vdots & & \vdots \\ 1/\tilde{\alpha}n1 & \tilde{\alpha}n2 & \dots & & 1 \end{bmatrix}. \quad (7)$$

Step2: Examine the consistency of the fuzzy pairwise comparison matrices. According to the research of Buckley (1985), if $\mathbf{A} = [\alpha ij]$ is a positive reciprocal matrix then $\tilde{\mathbf{A}} = [\tilde{\alpha}ij]$ is a fuzzy positive reciprocal matrix. That is, if the result of the comparisons of $\mathbf{A} = [\alpha ij]$ is consistent, then it can imply that the result of the comparisons of $\tilde{\mathbf{A}} = [\tilde{\alpha}ij]$ is also consistent. Therefore, this research employs this method to validate the questionnaire.

Step3: Compute the fuzzy geometric mean for each criterion. The geometric technique is used to calculate the geometric mean ($\tilde{r}i$) of the fuzzy comparison values of criterion I to each criterion, as shown in Eq. (8), where $\tilde{\alpha}in$ is a fuzzy value of the pair-wise comparison of criterion i to criterion n.

$$\tilde{r}i = [\tilde{\alpha}i1 \otimes \dots \otimes \tilde{\alpha}in]1/n \quad (8)$$

Step 4: Compute the fuzzy weights by normalisation. The fuzzy weight of the ith criterion ($\bar{\mathbf{w}}i$), can be derived as Eq. (9), where $\bar{\mathbf{w}}i$ is denoted as $\bar{\mathbf{w}}i$ = (Lwi, Mwi, Uwi) by a TFN and Lwi, Mwi, and Uwi represent the lower, middle and upper values of the fuzzy weight of the ith criterion.

$$\bar{w}i = \tilde{r}i \otimes (\tilde{r}1 \oplus \tilde{r}2 \oplus \dots \oplus \tilde{r}n) - 1 \quad (9)$$