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Existing Green Port Sustainable Practices under Fuzzy AHP Model: A Case Study of Karachi Port

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Abstract

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Keywords: Maritime transportation, Green Port Practices, Sustainable Development, Environmental Pollution Control, Fuzzy AHP Model

Authors:

Sharjeel Ahmad: (Corresponding Author)
PhD Scholar, Department of Public Administration, University of Karachi, Sindh, Pakistan.
Email: (motandas@gmail.com)

Syed Shahid Zaheer Zaidi: Assistant Professor, Department of Public Administration, University of Karachi, Sindh, Pakistan.

H. Shahrukh Zohaib: Assistant Professor, Department of Maritime Sciences, Bahria University Karachi Campus, Karachi, Sindh, Pakistan.

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Abstract

Maritime transport drives globalization and international trade. Ports worldwide handle 80% of seaborne trade by volume and 70% by value. Sustainable development is more important due to unexpected worldwide environmental changes. Ports are vital to economic progress. Port construction and operation polluted the environment, prompting the green concept. The present study used the "Fuzzy AHP Model"to assess Karachi Port's sustainable green port practices based on previous research. The study identified five key characteristics of a green port: little hazardous waste handling, a weak air and water pollution control system, poor port greenery, and habitat quality maintenance below international standards at Karachi port. Future research should create and apply solutions to improve this study's prioritized features. Innovative technology, policies, and collaborations can sustain green ports. Port and regional studies uncover green port best practices and contextual differences. Monitor and evaluate strategies to adapt to changing environmental standards and maritime transport issues.

Keywords: Maritime Transportation, Green Port Practices, Sustainable Development, Environmental Pollution Control, Fuzzy AHP Model

Contents

Authors:

Sharjeel Ahmad: (Corresponding Author)
PhD Scholar, Department of Public Administration, University of Karachi, Sindh, Pakistan.
Email: (motandas@gmail.com)

Syed Shahid Zaheer Zaidi: Assistant Professor, Department of Public Administration, University of Karachi, Sindh, Pakistan.

H. Shahrukh Zohaib: Assistant Professor, Department of Maritime Sciences, Bahria University Karachi Campus, Karachi, Sindh, Pakistan.

Introduction

The transportation of products by sea is the foundation of international commerce and a primary force behind the process of globalization. In the year 2021, ports all over the world managed about 80% of global trade in terms of volume and more than 70% in terms of value (Shoukat, & Xiaoqiang, 2022). According to Shoukat, (2022), these percentages are significantly greater in nearly all developing countries. Ensuring enduring sustainability development is becoming a progressively critical component of policy discussion on internationalization, trade and growth, environmental and climate sustainability, energy availability security, safety, and change in climate (Sherazi, 2023). This is because the increase in freight traffic is expected to continue for the foreseeable future. We are confronted with several

significant challenges as a result of the abnormal changes that have occurred in the global environment. These challenges include global climate change through warming, water, and land pollution, different wastage, air and water pollution, a layer of ozone reduction, universe annihilation, and the matter of swift energy consumption (Serry, 2023). The idea of sustainable development was pushed as a means of mitigating the destructive effects of the ongoing damage to the Earth.

Sherazi (2023) explores sustainability as a coordinated procedure of transformation that ensures the responsible use of resources, strategic investment decisions, the advancement of technology, and institutional reforms, all working together to improve both present and future capabilities in meeting human needs and aspirations. Sustainability also can be defined as the capacity to endure and maintain ecological balance, social equity, and economic prosperity over the long term (Mahmood, et al., 2024). In simpler terms, sustainability refers to the ability to meet the demands of the current generation without compromising the ability of future generations to meet their own needs. Sustainable development, at its core, acknowledges the connection between environmental changes, and societal, and monetary systems and pursues to advance fairness, fairness, and global responsibility (Notteboom, et al., 2020). Furthermore, sustainable development aims to promote the concept of global citizenship. Furthermore, Nizam et al. (2020) studied sustainable development involves the integration of the "triple bottom line," which comprises three elements: (1) ecological equilibrium (encompassing the well-being of natural ecosystems, reduction of resource depletion, and addressing changing climate), (2) long-term cost-effective constancy, and (3) social progress and fairness.

According to Li, Solangi, & Ali, (2023), seaports play a crucial role in enabling international trade, promoting the growth of the global economy, and establishing connections between different parts of the world through maritime transportation networks (Serry, 2023). They may also serve as a checkpoint for human-caused environmental contamination inputs resulting from activities associated with maritime traffic. Port managers are faced with new and crucial difficulties in terms of providing effectual seaport facilities also using their inimitable points to address universal ecological issues. The notion of green port operation and sustainable development has emerged as a necessary approach to combat the environmental pollution resulting from the construction and functioning of a port. The green idea in the context of port operation and development planning primarily encompasses three factors: energy conservation, environmental preservation, and ecological care (Notteboom, et al., 2020).

Karachi Port Trust (KPT)

The activities of the Karachi Port are managed by the Karachi Port Trust, which is operated under the supervision of the federal government. The Islamic Republic of Pakistan's Ministry of Maritime Affairs, on the other hand, is the entity that is accountable for its activities. A Board of Trustees oversees its operations as a trust entity. The Karachi Harbor Board was in charge of Karachi Port's administration from the years 1880 till 1887. It was Act IV of 1886 that established the Karachi Port Trust, and it went into effect on April 1st, 1887.

Nizam et al. (2020) there is a canal that is 13.5 meters deep and 11.5 kilometers long that is located in Karachi Port. Three liquid cargo berths are available for both POL and non-POL goods, while the port has thirty dry cargo berths, thirteen of which are located on the West Wharves and one on the East Wharves. At the moment, 33 seats are available. Ships with a maximum DWT of 75,000 can safely navigate the port at any time of the day or night, seven days a week. Several independent private stevedoring companies are responsible for the port's activities that do not involve the handling of containers. The Karachi International Container Terminal (KICT), which is managed by Hutchison, and the Pakistan International Container Terminal (PICT), which is handled by International Container Terminal Services (ICTS), were both established on a business-to-business (BOT) basis.

Emphasizing the green ecological model is crucial for keeping our atmosphere safe and healthy. However, what is even more vital is implementing the green concept in practical ways. The objective of this research is to endeavor to fulfill this job. The main aim of this study is to investigate the factors that contribute to the functioning of an environmentally friendly port. The "Analytical Hierarchy Process (AHP)" technique is best to assess the importance and order of ecological green safety port aspects. Afterward, the methodology is used to measure the enactment of different pragmatic cases related to green ports. Initially, this study investigates various green port criteria. Subsequently, a succinct presentation of the principles governing fuzzy AHP is provided. Furthermore, an Analytic Hierarchy Process (AHP) survey is employed to gather realistic statistics from different port enterprises, with the aim of emphasizing the importance and priority of green port

characteristics. The standards are subsequently employed to assess the port's performance. Conclusions are provided at the conclusion of the discussion (Li, Solangi, & Ali, 2023).

Objectives of the Study

1. To study Karachi Port's green operations, focusing on minimizing hazardous waste, improving air and water pollution management, increasing greenery, and meeting international standards for ecological sustainability.
2. To evaluate the impact of innovative technology, policy frameworks, and collaborative initiatives on sustainable green port practices at Karachi Port, addressing environmental challenges and adapting to changing maritime transport standards.

Related Literature Review

Ships and ports are essential elements of the "duo" system of maritime transportation. The term "duo" denotes the fundamental nature of maritime transportation, which consists of two essential elements: ships and ports (Hossain, Adams, & Walker, 2021). The operations conducted within the port not only have the capacity to impact the environment but also the maritime activities and transportation that occur on land. Due to the strong correlation between port operations and shipping operations, it is imperative to analyze previous research undertaken on shipping operations (Hashim, et al., 2023).

Research undertaken by the United Nations has shown that marine transportation is susceptible to the impacts of climate change. The effects of an event might vary in nature, extent, and severity, based on local conditions, transportation networks, designs, rules, and the ability to adjust and minimize costs (Habib & Iqbal, 2022). The likelihood of immediate consequences involving the infrastructure, operations, and maintenance of maritime transportation is greater. According to Chiu, Lin, & Ting, (2014) transport in the maritime sector for different facilities may perhaps be indirectly affected by changes in demand caused by the impact of environmental and weather changes, in trading asset judgments, demographics of participants, agronomic manufacture, forestry, energy consideration, energy petition, and different fishing commotion (Mannan, Haq, & Rashid, 2023).

Commercial shipping emissions have been extensively studied to mitigate their adverse environmental impacts. According to Botana, Fernández, and Feijoo (2023), there are three main strategies that can be employed to reduce greenhouse gas (GHG) emissions from maritime transportation. Technical measures encompass various strategies to enhance the efficiency of ships. These include the adoption of more streamlined ship hulls, engines that consume less energy, improved propulsion systems, the utilization of alternative fuels like fuel cells, biofuels, or other substitutes, the practice of "cold ironing" in ports (which allows ships to draw electrical power from shore sources), the implementation of exhaust emission trapping devices like scrubbers, and the incorporation of sails to minimize power requirements (Aslam, et al., 2023). The major types of market-oriented appliance procedures are carbon tax schemes and emissions trading. Finally, operational solutions are mainly focused on improving logistics through speediness optimization, better steering, developed fleet strategic formation, and additional associated strategies (An, et al., 2021).

Ali et al. (2020) put forward a cost-effectiveness assessment approach for technical and operational mitigative interventions so that CO2 emissions by the shipping industry could be reduced. This approach is based on the development of a metric, which makes the evaluation possible, and a criterion that permits making decisions. The objective is to define the effectiveness of those measures in reducing CO2 emissions due to shipping. It is the technique found in line with what the Diplomatic Panel on Macroclimate Changing recommended, aligned to the regulatory approach used by the International Maritime Organization as it tries to find solutions to problems related to environmental preservation and safety.

For example, in comparison with the international safety management code to reduce CO2 emission and ISO 50001, An et al. (2021) have found that SEEMP does not hold essential elements similar to the latter standards of management systems. These provisions include those for policy and management reviews. Next, the best practice to overcome major issues more comprehensively is underlain by the ISO 50001 standard. The mentioned factors encompass monitoring, energy audits, design, and procurement methods. Reducing the speed of a vehicle is a widely employed operational tactic in the real world to minimize fuel consumption, resulting in cost savings and pollution reduction (Ilyas, et al., 2023). In order to account for the increased time that ships spend at sea due to slow steaming, ports can propose creative approaches to minimize interruptions and maximize efficiency in port services. This will help maintain the agreed schedule set by shipping companies (Younus, et al., 2023).

Asghar (2023) further examines the consequences of slow steaming on the environmental efficiency of liner transportation. They discovered the following findings by employing the simulation technique: (1) While slow steaming effectively reduces carbon dioxide emissions, it may not always be cost-effective in terms of operational expenses. Slowing down the speed of the voyage can lead to additional savings in CO2 emissions. Nevertheless, slow steaming is only effective in reducing operating costs when the vessel's speed is between 25 and 13.6 knots. The lowest operating costs are achieved at a speed of 18.6 knots. Additionally, increasing the size of the vessel on a loop helps to decrease CO2 emissions at all speeds during the voyage (Chau, et al., 2023). However, this has a detrimental effect on both the expenses of running the operation and the efficiency of energy consumption, as measured by the CEEI index. Additionally, considering the current average speed of 15-17 knots, it can be determined that over 90 percent of CO2 emissions have already been decreased on the Asia/Europe route, according to the simulation results. Lastly, the simulation yielded three strategic speeds for the voyage, with 17.4 knots being the most advantageous strategy. If liners can optimize the reduction of CO2 emissions while simultaneously decreasing their operational expenses, they will be able to fulfill the political objective of the International Maritime Organization (IMO) (Sherazi, 2023).

According to Asghar, (2023), the Green Port Factors Studies on the environmental problems that are associated with ports exhibit a wide range of topics. In recent years, one of the primary concerns for port operations has been the reduction of environmental impacts to the greatest extent possible. Ports have been working towards achieving a "greener" status by implementing recent technological advancements, modernizing their infrastructure, and reducing the amount of energy that is used that is not essential (Khan, Khan & Nallaluthan, 2023). It is generally accepted that the port is a system that is made up of numerous diverse components, all add to the ecological footmark that it takes. It is possible to divide these into three categories: maritime activities, import operations, and urban transportation (Sherazi, 2023). Traffic congestion, air pollution, noise pollution, and carbon dioxide emissions are only some of the unfavorable side effects that have developed in tandem with the expansion of transportation activity. Both the construction of new transport infrastructures and the development of existing ones, such as airports, highways, trains, and ports, have the potential to produce detrimental effects on the surrounding environment (Khan, Khan & Nallaluthan, 2023). Because of this, the green idea is attainment favor as a means of developing and operating port trading to inhibit the dilapidation of the atmosphere, the loss of biodiversity, and the use of natural resources in a manner that is not sustainable (Mahmood, et al., 2024).

Nizam et al. (2020) the "Organization for Economic Cooperation and Development (OECD)" conducted research Notteboom, et al. (2020) found that well-functioning ports have the potential to play a substantial role in fostering financial growth in the contiguous areas and a larger vicinity. However, the deeds that take place at ports can have considerable adverse effects on the environment (Serry, 2023). The operations of sea transport have an impact on the environment not only within the ports themselves but also in the immediate neighborhood of the ports.

According to Mahmood, et al. (2024), noise from ship engines and gear used for loading and unloading, exhausts of particles, carbon dioxide, nitrogen oxides, and sulfur dioxide from the ship's main and auxiliary engines, and dust from the handling of commodities such as grain, sand, and coal are all examples of a few of the consequences that can be caused by these activities. Road and rail traffic that travels to and from the port region contributes to the environmental challenges that already exist (Sherazi, 2023).

Three subcategories can be used to classify the environmental impact of ports. These divisions are as follows:

1. difficulties created by the port bustle the situation;
2. difficulties initiated at sea by ships' vocation at the harbor; and
3. emanations starting multimodal transportation systems serving the locality of the port.

As a result of the extensive variety of these impacts, it is necessary to implement a wide variety of policy instruments to effectively accomplish ecological influences. Furthermore, the "optimal" combination of policy apparatuses is expected to fluctuate ominously from one port to the next.

Notteboom, et al. (2020) highlighted that seaports, being frequently located in or close to residential areas and environmentally delicate estuaries, commonly raised the following environmental concerns:

- Air pollution resulting from port operations, specifically smog and particulate pollution,
- Wetland loss or degradation,
- Destruction of fisheries and endangered species,
- Discharge of wastewater and stormwater,

- Severe traffic congestion,
- Noise and light pollution,
- Loss of cultural resources,
- Contamination of soil and water due to leaking storage tanks,
- Air releases from chemical storage or fumigation activities,
- Generation of solid and hazardous waste.

Therefore Based on their research, they determined that multiple strategies are necessary to reduce effluence at seaports that are shifting towards a sustainable operational model that benefits the local area without harming the well-being and uprightness of people and environmental systems (Sherazi, 2023).

Shoukat and Xiaoqiang (2022) identified several significant environmental factors in seaports. These include emissions to the air, such as smoke, solid elements, and vigor, with dust being a major contributor. Releases to marine, such as wastewater and unintentional reliefs during packing/dropping processes, are also important. Industrial activities can lead to the release of soil, while activities like dredging can impact marine sediments and the seabed. Noise, which can affect both the population and fauna, is another factor. Nizam et al. (2020) Seaports also generate waste and dispose of dredging materials. Terrestrial habitats can be lost or degraded, and marine ecosystems can be altered. Odors, reserve ingestion, and seaport growth, both on land and at sea, are also significant factors. Mahmood, et al. (2024) research reveals that seaport operations in industrial ports have the capacity to generate a combined total of 63 distinct environmental impacts. It is imperative to enforce and enhance the regulation of these activities in order to mitigate the severity of the situation. The environmental impacts can be categorized into various types, such as atmosphere pollution, sound contamination, redolence pollution, water pollution, sand pollution, generation of garbage (including urban waste and hazardous waste), consumption of resources, and other possible effects.

Khan, Khan, and Nallaluthan (2023) focus specifically on Poland and outline the top 10 environmental issues of three Polish ports in 2012. The priorities encompassed in this list are as follows:

- Disposal of waste from ships, namely sewage,
- Mitigation of noise,
- Control of dust,
- Proper disposal of dredged materials,
- Development of port infrastructure on land,
- Preservation of conservation areas,
- Management of ballast water,
- Reduction of emissions from ship exhaust,
- Optimization of energy use, and
- Fostering a positive relationship with the local population.

The focus of most research on maritime pollution control has been on technical aspects and operational matters concerning deep-sea shipping. However, a study conducted by Mahmood, et al. (2024) reveals that without proper coordination, spill-over of pollution and competition between ports can lead to distorted taxation and constraints on emissions. Consequently, they are promoting the collaboration of regional ports to minimize pollution, despite potential competition among ports in the same area. Serry (2023) employed "Data Envelopment Analysis (DEA)" to examine the negative outputs produced by ports, notably carbon dioxide emissions. This study was carried out using data obtained from ports in Korea. He focuses on analyzing the environmental effectiveness of Korea's ports and strives to calculate the potential reduction in carbon dioxide emissions that might be accomplished by seaports in the state. Based on the study's findings, Korean seaports are considered economically disorganized. However, considering both financial and ecological enactments together, they are regarded as environmentally efficient (Shoukat, & Xiaoqiang, 2022).

Past studies have demonstrated a diverse range of research areas concerning the issues faced by green ports. According to Khan, Khan, and Nallaluthan (2023), different studies globally have been conducted to identify the causes of pollution. The researchers are mostly focused on studying various forms of pollution. To address the various forms of pollution, most research suggests utilizing specific control measures. Furthermore, several port authorities worldwide have adopted goals and implemented strategies to alleviate the contrary environmental effects caused by their ports (Serry, 2023). Only a few studies have been carried out to examine the process through which a port might select ecological controller measures based on the precedence of green seaport characteristics. The objective of this study is to fill the identified gap. Shoukat, and Xiaoqiang (2022) categorized twelve distinct green port initiatives by thoroughly examining academic literature and the green seaport or ecological procedural documents of numerous seaport administrations. These measurements can be classified into five separate features: environmental quality, energy and resource usage, waste management, habitation quality and greens, and societal involvement.

Several particular measures can be implemented to accomplish the goal of building and running an environmentally friendly port. Nizam et al. (2020)

these actions encompass a range of measures aimed at addressing various forms of pollution, including air pollution, water pollution, noise pollution, and land and sediment pollution. They also include such things as strategies for material selection, strategies for water consumption, strategies for energy use, strategies for waste management, dangerous waste management, territory of superiority and greenery, communal preferment and education, and personnel training. Quite likely, it would be hard or even impossible to oblige every port authority to do all the above-mentioned activities in order to become a sustainable port. Activities in relation to the green port should, therefore, be conducted sequentially through a range of activities. A more detailed study of the importance of green port initiatives will benefit the environmental status of these ports while determining the optimal set and sequence. The "Analytic Hierarchy Process (AHP)", developed by Saaty (1977) Shoukat, and Xiaoqiang (2022) later enhanced with the introduction of fuzzy logic, known as Fuzzy AHP, can be used to assess the relative significance of green port characteristics. If a port is unable to fully implement all of the environmentally friendly measures, the port authorities have the option to select certain prioritized items for execution in the initial phase, and then gradually achieve a fully sustainable port operation. This is an effective and feasible solution to the problem.

The Methodology of Research

AHP is an acronym for the "Analytical Hierarchy Process". The "Analytic Hierarchy Process (AHP)" is a widely used method for modeling particular decision-making procedures that involve several considerations. Since then, it has been commonly used in company planning, portfolio selection, benefit/cost analysis conducted by government agencies for resource allocation, and the determination of the placement of an international logistics center. An Analytic Hierarchy Process may be broken down into four major components in its development. First, there is the construction of the hierarchical system by breaking down the problem into interrelated components arranged in a hierarchy.

Second, generate input in the format of a pairwise comparison matrix. This is a matrix comparing the qualities of the decision elements against one another with respect to their relative importance. The third step is to provide a brief summary of the decision along with the comparative importance. Finally, in order to find out the ratings of the choice alternatives and techniques, it becomes imperative to determine the relative weights of the decision components combined.

The fuzzy AHP approach can be regarded as an enhanced analytical method that was derived from the standard AHP. When using the conventional Analytic Hierarchy Process (AHP), the comparisons between different options at each level, with the goal of selecting the optimal alternative, are conducted using a nine-point scale. Hence, the utilization of Saaty's Analytic Hierarchy Process (AHP) entails several limitations, which are as follows:

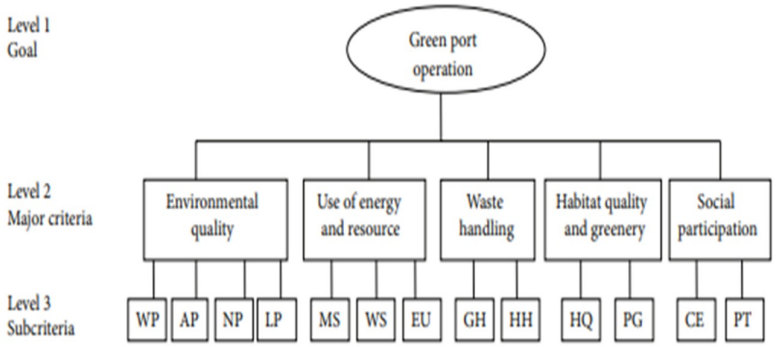
1. The AHP method is mainly used in situations where quick decisions need to be made.
2. The AHP method produces and deals with a highly uneven scale of judgment.
3. The AHP method does not consider the uncertainty that arises from converting one's judgment into a numerical value.
4. The ranking produced by the AHP method is not very precise.
5. The subjective judgment, selection, and preference of decision-makers greatly influence the results obtained through the AHP method.

In addition, decision-makers are always faced with the restrictions of ambiguity and many interpretations while evaluating options. Furthermore, it is commonly recognized that the assessment of qualitative attributes by humans is necessarily subjective and, hence, imprecise.

Due to the ambiguity and uncertainty in assessments, a standard AHP may not adequately represent the ideas being examined by decision-makers through a straightforward, paired comparison. While the discrete scale of AHP offers simplicity and convenience, it fails to consider the uncertainty associated with converting one's experience into a numerical value. To overcome the limitations of the conventional AHP, fuzzy logic is integrated into the pairwise comparison process. The methodology being referred to is commonly referred to as the Fuzzy Analytic Hierarchy Process (FAHP). FAHP is a powerful tool for handling inherent fuzziness in some variables of decision-making. Generating fuzzy pairwise comparison matrices basically involves representing comparisons made by professionals in the form of triangular fuzzy integers.

Figure 1

"AHP model for green port assessment"



WP: pollution of water; AP: pollution of air, NP: noise generation LP: land and sediments contamination, MS: chose materials, WS: water usage, EU: fuel consumption, General trash management, GH: HH: managing hazardous materials Headquarters: preservation of habitat quality, PG: port landscaping, CE: community education and development PT: port staff training.

Table 1

Respondents of the Study

Type of organization	No. of respondents	Percentage %
Port Management	10	50.0
Maritime authorities	07	35.0
Research/Training institute	03	15.0
Total	20	100

Table 2

Major Criteria and Sub criteria of Greenport Policy Status

Major Criteria	Sub-criteria	Policy Status	Implementation Status
Environmental Quality	Water pollution	Developed	Partially Implemented
	Air pollution	Policy formulated but not approved	-
	Land and sediment pollution	Policy formulated but not approved	
	Noise pollution	Policy formulated but not approved	
Use of Energy and Resource	Energy Usage	Policy not develop	
	Materials Selection	Developed	Partially Implemented
	Water Consumption	Policy not Develop	
Habitat Quality and Greenery	Port Greenery	Policy not Develop	
	Habitat quality maintenance	Developed	Partially Implemented
Waste Handling	Hazardous waste handling	Developed	Implemented
	General waste handling	Developed	Implemented
Social Participation	Port staff training	Developed	Partially Implemented
	Community promotion and education	CSR Developed	Not Implemented

Table 3

Existing Status of Karachi Port Towards Greenport Standards

Major Criteria	Sub-criteria	Existing Status
Environmental Quality	Water pollution	Very Poor
	Air pollution	Poor
	Land and sediment pollution	Very Poor
	Noise pollution	Poor
Use of Energy and Resource	Energy Usage	Poor
	Materials Selection	Good
	Water Consumption	Poor
Habitat Quality and Greenery	Port Greenery	Very Poor
	Habitat quality maintenance	Good
Waste Handling	Hazardous waste handling	Good
	General Waste Handling	Good
Social Participation	Port Staff Training	Poor
	Community Promotion and Education	Very Poor

Table 4

Existing Action Plans of Karachi Port Towards Greenport 2030 Goals

Major Criteria	Sub-criteria	Existing Actions	Goals 2030
Environmental Quality	Water pollution	No ship is allowed to Drain waste	50 % Minimize
	Air pollution	No ship is allowed to Use a Diesel Engine on Berth	70 % Minimize
	Land and sediment pollution	All ships and Port Employees Dispose of Wastage in Specific Places	75 % Minimize
	Noise pollution	No ship is allowed to Use Diesel Engine & klaxon at Port	70 % Minimize
Use of Energy and Resource	Energy Usage	Ship only allow to use Port Electric	50 % Green Energy Utilized in Port
	Materials Selection	According to International Standards	Increase Greenport status by 50 %
	Water Consumption	Karachi Port Authority Develop Policy	Save water Increase Greenport status by 50 %
Habitat Quality and Greenery	Port Greenery	Karachi Port Authority Develop Policy and implement in 2024	Increase Greenport status by 80 %
	Habitat quality maintenance	Karachi Port Authority Implement Policy	Increase Greenport status by 60 %
Waste Handling	Hazardous waste handling	Karachi Port Authority Follows International Standards	Increase Greenport status by 40 %
	General Waste Handling	Karachi Port Authority Follows International Standards	Increase Greenport status by 80 %
Social Participation	Port Staff Training	Karachi Port Authority Conduct different Training	Increase Greenport Awareness

Major Criteria	Sub-criteria	Existing Actions	Goals 2030
	Community Promotion and Education	Programs for employees and stakeholders	100 %
		Karachi Port Authority Follows National Standards for CSR	Increase Greenport Awareness 70 %

Findings of the Study (Karachi Port's Current State)

Environmental Quality

- The water pollution at Karachi Port is assessed as very poor, and no policy for improvement has been formulated or approved.
- Air quality is poor, and the policies have been drafted but are yet to be approved for implementation.
- Land and sediment pollution is also rated very poor, though policies have been formulated and not approved.
- Noise pollution is ranked as poor, while policies have been drafted but not approved.

Use of Energy and Resources

- The energy usage at Karachi Port is graded as poor, and no policy has been developed to address it.
- Materials selection: good. Policies have been developed and partially implemented.
- The rating for water consumption is poor, and no policy has been developed to address it.

Habitat Quality and Greenery

- The port greenery is rated very bad, and no policy has so far been developed to address it.
- The habitat quality is in good maintenance, as its policies are developed and partially implemented.

Waste Handling

- The handling of hazardous waste at Karachi Port is rated good; policies have been developed and implemented.
- General waste handling is also graded well with policies in hand and their implementation.

Social Participation

- A low score on the rating of port staff training and policies developed, partially implemented.
- Community Promotion and education: very poor rating. CSR was developed but not implemented.

Conclusion

The present study provides important insight into the existing status of environmentally friendly and sustainable port procedures at Karachi Port. The findings reveal significant disparities among several environmental elements, with water and air pollution being seen as the most detrimental. While certain aspects, such as material selection and hazardous waste management, show positive progress, there are other areas that require immediate attention. These include the environmental sustainability of the port area and the level of community engagement. The lack of effective policies and tools for crucial sectors emphasizes the urgency of taking immediate action to mitigate the pace of environmental degradation and promote sustainable development. To achieve international green port standards, it is necessary to make a concentrated effort to create and enforce effective rules, utilize innovative technology, and encourage collaborative activities. This will enhance sustainability and improve the performance of Karachi Port. Consequently, this will establish a solid basis for future research and policy interventions aimed at maximizing the environmental friendliness and sustainability of the maritime transportation industry.

Future Directions

The current study proposes potential directions for future research and chances for further investigation. Firstly, it is necessary to assess the efficacy of the green port activities at Karachi Port and take appropriate actions to achieve the intended environmental objectives. Longitudinal studies can track the path of sustainability indicators over time and alter priorities in objectives. Comparative studies conducted across various ports and regions can reveal the most effective techniques and contextual aspects that define the effectiveness of environmentally friendly ports. By employing comparative approaches, it becomes possible to identify strategies that may be applied in other contexts and incorporate the lessons learned into policy development and execution. Future research should focus on integrating new technologies to build renewable energy systems and smart port solutions, in order to enhance environmental sustainability and

operational efficiency. The stakeholders, including port authorities, government agencies, industry players, and local communities, must collaborate to promote collective action and foster a culture of sustainability in maritime transport. In order to advance the sustainability agenda and minimize the environmental impact of port operations, it is imperative to prioritize continuous improvement, innovation, and collaboration in future endeavors.

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