A SYSTEMATIC STUDY ON GREEN PORT STRATEGIES OF SUSTAINABLE PORT OPERATIONS

Project report submitted to the School of Maritime Management, Indian Maritime University in partial fulfilment for the requirements for the award of degree of

MASTER OF BUSINESS ADMINISTRATION

In

PORT AND SHIPPING MANAGEMENT

Submitted by

GANESHKUMAR M

(Reg. No. 2303304015)

Under the guidance of

Dr. SEKAR M

Assistant professor, SMM

INDIAN MARITIME UNIVERSITY

(A central University, Government of India)

SCHOOL OF MARITIME MANAGEMENT

CHENNAI

MAY 2025

DECLARATION

I, **GANESHKUMAR M, Reg. No.2303304015** student of **School of Maritime Management, Indian Maritime University**, pursuing **MBA in Port and Shipping Management** hereby declare that this submission of this project report titled "**A Systematic Study on Green Port Strategies of Sustainable Port Operations**"- has been prepared by me towards the partial fulfilment of the Master of Business Administration in Port and Shipping Management under the supervision of **Dr. Sekar M** Assistant Professor SMM, Indian Maritime University, Chennai Campus. I also declare that this project report is my original work and has not been copied from any other report previously submitted for the award of any degree, fellowship or other in the similar title.

Place: Chennai

Date: 26/05/2025

GANESHKUMAR M

Reg. No: 2303304015

CERTIFICATE

This is to certify that this project reported "A Systematic Study on Green Port Strategies of Sustainable Port Operations" is submitted in partial fulfilment for requirement of awarding the degree.

Dr. M Sekar

Assistant Professor

Dr. B Swaminathan

Associate Professor & Head, SMM

External Examiner

Place: Chennai

Date: 26/05/2025

ACKNOWLEDGMENTS

First and foremost, I would like to thank God the Almighty who has granted countless blessings, knowledge and opportunity to complete this project to its fullest.

I would like to thank my parents for the moral support and cooperation throughout the program. My heartfelt and sincere thanks to **Dr. B Swaminathan**, Associate professor Head SMM, Indian Maritime University, Chennai Campus who gave me the golden opportunity to do this wonderful project on the topic "**A Systematic Study on Green Port Strategies of Sustainable Port Operations".** I pay him my deep sense of gratitude for guiding me.

I would like to express my deep sense of gratitude of **Dr. Sekar M** Assistant Professor SMM, Indian Maritime University, Chennai Campus. For his esteemed guidance and expert suggestions in each step of the project, alleviating inspiration, encouraging and kind supervision in the completion of my project.

I am also thankful to faculty members, library staffs, my friends and my well-wishers who were very cooperative during my project in providing appropriate guidance and support without whom this project would not have been completed successfully.

GANESHKUMAR M

ABSTRACT

Today the globe increasing an environmental protection and sustainable development, ports across the globe are embracing green port policies to reduce their ecological impact without compromising on operational efficiency. This research study examines the implementation, efficacy, and struggles of green port strategies in ensuring sustainable port operation. Through an examination of peer-reviewed literature, case studies, and policy frameworks of major ports worldwide, the research identifies the most important sustainability initiatives such as the use of shore power, waste management, energy-efficient facilities, and emissions reduction programs. The study also examines how technological innovation, stakeholder engagement, and policies of regulation contribute to facilitating sustainable changes. The Findings indicate that although green strategies significantly contribute to environmental and economic gains, their implementation is significantly tied to regional context, governance arrangements, and investment capacity. The research concludes by presenting a strategy for combining port management and green practices and pointing out avenues for future research and policy-making towards further promoting eco-friendly maritime logistics**.**

TABLE OF CONTENTS

LIST OF FIGURES & TABLES

CHAPTER – I

INTRODUCTION

1.1. Background and context of green port

With growing global environmental issues, the shipping industry is now more and more emphasizing green practices. Ports, being pivotal hubs in international trade and logistics, have historically been major polluters because of heavy cargo handling, ship traffic, and industrial processes. In response to these issues, the idea of green ports has been developed as a major strategy to harmonize port operations with social responsibility, economic efficiency, and environmental sustainability. India in particular has a sizable maritime sector, with 12 major and more than 200 non-major ports spread across its 7,500 km of coastline and extensive network of navigable waterways. The maritime sector is essential to the nation's overall trade and development, accounting for 95% of its trade volume and 65% of its trade value.

In order to lessen negative impacts on the environment and nearby populations, a green port is a seaport that integrates environmentally friendly procedures and technology into its operations. This includes actions to stop or reduce pollution of the air and water, properly dispose of trash, preserve energy and natural resources, and promote the use of renewable resources. Green ports often seek to strike a balance between environmental preservation and port expansion. They implement systems and policies that help global efforts to combat climate change and ocean pollution while still adhering to environmental standards. According to estimates from the World Health Organization (WHO), air pollution causes eight million deaths annually and is a sustained danger to health (World Health Organization, 2024). A large portion of this danger is caused by shipping and health, with an estimated eight million deaths annually as a result (World Health Organization, 2024). This danger is greatly increased by shipping, particularly in coastal regions. Shipping contributes over 17% of NO2, 6-8% of SO2 emissions, 8% of CO, and 7-8% of O3 emissions globally, all of which have a major negative impact on the environment and human health (Zis et al., 2019). Standards such as ISO 14001 (Environmental Management), the Eco Ports network, or UN SDG compatibility are typically used to certify or guide green ports.

Pillars of Green Ports Concept:

- Green port as a prerequisite for green shipping Maritime Shipping spans the world and to a large extent, takes place outside of territorial waters.

- Green port as an ecologically built and operated port. This core of the green port concept is about port infrastructure and superstructure is to be built and operated as ecologically as possible.
- Green port as a prerequisite for ecologically port hinterland transport.

Fig 1.1. Pillars of Green port

sources:www.desapex.com%2Fblog-posts%2Fgreen-ports-charting-a-sustainable-course-for-maritime-trade

Key Features of Green Ports:

- Air Quality and Emissions Control
- Energy Efficiency and Renewable Sources
- Waste and Water Management
- Sustainable Transport and Logistics
- Digitalization and Smart Port Technologies
- Eco-Friendly Infrastructure
- Monitoring and Certification
- Community Engagement and Transparency

Examples of Green Ports:

- Port of Rotterdam, Netherlands
- Port of Los Angeles, USA
- Port of Singapore
- Port of Gothenburg, Sweden
- Port of Busan, South Korea

Major ports Green Initiatives:

- **Kandla Port (Deendayal Port), Gujarat**

  Located on the Gulf of Kutch, Kandla Port is one of India's largest ports by cargo volume, handling a diverse range of goods including crude oil, chemicals, and agricultural products.
- Solar Power Projects.
- Dust Suppression Measures
- Water Conservation

- **Mumbai Port, Maharashtra**

  Mumbai Port is one of the oldest ports in India, handling bulk cargo, petroleum products, and chemicals.
- Renewable Energy Adoption

- Energy Efficiency Measures
- Pollution Control

- **Jawaharlal Nehru Port (Nhava Sheva), Maharashtra**

  India's largest container port, it handles around 50% of the total container cargo**.**
- Solar Power Generation
- Emission Reduction
- Energy Efficiency Projects

- **Mormugao Port, Goa**

  Situated in Goa, Mormugao Port is a deep-water port primarily handling iron ore exports
- Harit Shrey Program [It is the first Indian port to be listed on the Environmental Ship Index (ESI) portal]
- Emission Reduction Targets

- **New Mangalore Port, Karnataka**

  Located in Karnataka, New Mangalore Port handles crude oil imports, fertilizers, coal, and edible oils**.**
- Solar Power Projects.
- Energy Efficiency Measures
- Pollution Control

- **Cochin Port (Kochi), Kerala**

  A natural port with strategic importance, it handles crude oil, containers, and LPG.
- Solar Power Projects
- Floating Solar PV Project
- Onshore Power Supply

- **Chennai Port, Tamil Nadu**

  One of the oldest ports, it primarily handles containers, automobiles, and general cargo
- Renewable Energy Targets
- Electrification of Equipment.

- Emission Reduction

- **Ennore Port (Kamarajar Port), Tamil Nadu**

  India’s first corporatized port, it specializes in handling coal, iron ore, and automobiles

- Solar Power Project.
- Energy Efficiency Measures
- Pollution Control

- **Tuticorin Port (V.O. Chidambaranar Port), Tamil Nadu**

  Handles containers, coal, salt, and general cargo.

- Solar Power Projects.
- Energy Efficiency Measures
- Emission Reduction

- **Visakhapatnam Port, Andhra Pradesh**

  One of the deepest ports in India, it handles coal, iron ore, and petroleum products.

- Solar Power Projects
- Energy Efficiency Measures
- **Paradip Port, Odisha**

  Paradip Port is one of India's busiest ports, handling a diverse range of cargo including coal, iron ore, and crude oil.

- Mechanization and Automation
- Green Hydrogen and Ammonia Hub
- Carbon-Free Transport
- Afforestation Programs

- **Syama Prasad Mookerjee Port (Kolkata), West Bengal**

  The port has recognized the need to curb pollution and has initiated several green initiatives to promote sustainability**.**

- Shore-to-Ship Electricity Supply
- Wastewater Treatment
- Electrification of Cargo Handling Equipment

- Solar Power Projects

1.2. Importance of Sustainable port Operations

The significance of sustainable port operations is complex and increasingly in the context of international trade and green consciousness. As critical points in the global supply chain, ports enable more than 80% of international trade by volume, thus their operational performance and environmental impact matter. Unsustainable activities not only destroy local ecosystems and affect public health in nearby communities but also lead to climate change due to greenhouse gas emissions. Embracing green practices is not only a choice but now the need for ports to realize sustainable long-term profitability and competitiveness. Environmentally, green ports install mechanisms that affect air contaminants and carbon footprint through electric driving of machines, encouragement of ship shore power, and funding on renewable resources such as wind and solar energy. They also emphasize water quality via perfect treatment of wastewater, efficient prevention and response to spills, and sustainable water management. Waste management is also an important aspect, emphasizing reduction, reuse, recycling, and safe handling of hazardous waste to avoid land and ocean pollution.

Economically, sustainable operations will also result in meaningful cost savings through enhanced energy efficiency, lower waste disposal costs, and decreased environmental compliance expenses. Investing in good infrastructure can also improve operational effectiveness and attract companies that value sustainability, thereby improving competitiveness and potentially creating new market opportunities. A good environmental reputation can enhance relations with regulatory authorities and local communities, averting costly delays and legal disputes. Socially, sustainable ports add to the quality of life for communities around them by minimizing air and noise emissions, enhancing the public health and making green employment possibilities. Interaction with neighborhood stakeholders and maintaining transparency through operations builds belief and cooperation. Sustainable ports also serve the essential purpose of developing resilient supply chains to counter environmental and social shocks, promoting economic stability and security overall. Port initiatives aimed at promoting gender equality among port workers further underscore broader social responsibility undertaken by sustainable ports. The shift towards sustainable port operations is crucial in reducing environmental degradation, promoting economic resilience, and advancing social equality. Through combining financial, environmental, and social issues into their primary

plans and regular activities, ports can themselves become safe, effective, and socially sensitive, playing an essential part towards an environmentally friendly global trade and the globe.

Fig 1.2. Sustainable port operations

Sources:https%3A%2F%2Fwww.connectanetwork.com%2Fthe-role-of-major-global-ports-in-sustainable-logistics

1.3. Recent Initiatives taken by India

NATIONAL CENTRE OF EXCELLENCE IN GREEN PORTS AND SHIPPING (NCOEGPS)

The National Centre of Excellence on Green Ports and Shipping (NCoEGPS) is a joint understanding between the Ministry of Ports, Shipping and Waterways (MoPSW), Government of India, and The Energy and Resource Institute that was established during November 2023. The Centre is endorsed by major Indian ports such as (i) Cochin Shipyard Limited (ii)

Deendayal Port Authority (iii) Paradip Port Authority (iv) V.O.C Port Authority. The Centre carries out various research on policy and regulation facilitating green ports, green shipping and blue economy, alternative technologies and DPRs that will facilitate carbon neutrality and circular economy (CE) in shipping industry in India. The tasks that will be taken by the NCoEGPS will give the decision taking at a national and sub-national level with methodology and framework to achieve carbon neutrality steps, to fulfill (and surpass) commitment under Paris Accord through process electrification, renewable energy, biofuels and green infrastructure.

Greenfield Major Port at Vadhavan: The Central Government gave its project proposal approval for the "Development of an all-weather greenfield Major Port at Vadhavan" in Maharashtra in June 2024.Vadhavan Port is being constructed by Vadhavan Port Project Limited (VPPL), a joint venture company of Jawaharlal Nehru Port Authority (JNPA) and Maharashtra Maritime Board (MMB). The estimated project cost of INR 76,220 Cr. includes investment of INR 38,976 Cr. towards core infrastructure development (including INR 17,709 Cr. for reclamation and dredging work through PPP mode) and INR 37,244 Cr. towards development of terminal and other commercial infrastructure through PPP mode.

Green Hydrogen Hubs: Deendayal, Paradip, and VOC Ports are being set up for green hydrogen production, storage, and export as the India's National Green Hydrogen Mission. Paradip is building a jetty specifically for the handling of green hydrogen/ammonia. DPA has leased 3,400 acres of land to develop green hydrogen production, storage, and export facilities in July 2024. In addition, VOCPA is developing a demonstration plant for production, storage, and power generation using fuel cells. VOCPA has already leased 500 acres of land for developing green hydrogen production and storage facilities. A pilot project is also for green hydrogen and its derivatives' storage, refueling, and bunkering facilities. PPA has also started the process of building a jetty for the handling of green hydrogen or green ammonia, and about 40 acres of standby area for interim storage facilities**.**

source: shipmin.gov.in%2Fpublication%2Fannual-reports

MARITIME INDIA VISION 2030

Maritime India Vision 2030 (MIV 2030) – A Strategic Blueprint for India's Maritime Future

The **Maritime India Vision 2030 (MIV 2030)** is a ten-year master plan for the overall growth of India's maritime industry. Initiated by the Ministry of Ports, Shipping and Waterways, the vision includes more than 150 projects under ten interconnected themes, each designed to propel India to leadership in the international maritime world. With an estimated investment of ₹3-3.5 lakh crore, MIV 2030 aims to modernize ports, increase logistics efficiency, encourage green and sustainable shipping, and increase India's shipbuilding and repair capacity. A key thrust area of MIV 2030 is the creation of world-class port infrastructure through capacity expansion, the initiation of mega-port clusters, and the upgradation of existing facilities. The vision also gives importance to end-to-end logistics efficiency by minimizing expenditure and enhancing competitiveness through technology deployment and the initiation of a National Logistics Portal (Marine). Increasing cargo and passenger transportation through coastal shipping and inland waterways is another primary goal, with the aim of increasing environmentally friendly and efficient transport solutions.

MIV 2030 gives special importance to establishing India as a world hub for shipbuilding, repair, and recycling. It also strives to improve India's position as a leading seafaring nation by emphasizing world-class education, research, and training. Additionally, the vision advocates a safe, sustainable, and green maritime industry through more utilization of renewable energy and application of eco-friendly measures. Through the consolidation of policy framework and educational structures and enhanced global collaboration, MIV 2030 seeks to realize the full potential of India's maritime economy, propelling economic growth and international standing. While MAKV 2047 takes this a step further with a longer time horizon, MIV 2030 provides the essential foundation for these longer-term aspirations.

MARITIME AMRIT KAAL VISION 2047

The **Maritime Amrit Kaal Vision 2047 (MAKV 2047**) is India's long-term vision to transform its maritime sector by the country's hundred year of independence. The Maritime India Vision 2030 serves as the foundation for MAKV 2047, which offers over 300 concrete actions in 11 categories. This plan seeks to build world-class ports, increase logistics efficiency, foster green practices, and establish India as a world maritime leader. Some of the main areas of

concentration in MAKV 2047 are an immense increase in port capacity by establishing mega ports and transshipment facilities, coupled with the digitalization of current port infrastructure and operations. High priority is given to enhancing multimodal connectivity for unhindered movement of cargo. Additionally, MAKV 2047 places emphasis on green shipping and building green hydrogen clusters at key ports to ensure ecological sustainability. In addition, it aims to capitalize on the full potential of cruise tourism and waterways in hinterland to reap economic benefits, as well as enhance regional integration. Another equally important aspect is skill development for the maritime personnel to provide the talent pool for the growth of the sector. The vision also calls for a significant expansion of India's shipbuilding and repair capabilities in order to rank among the top 5 shipbuilding nations in the world by 2047.

The execution of this grand vision is being led by theme-based Neel Arth Vision Implementation Cells (NAVIC) with a perspective to focused advances on many fronts. Efforts in recent times are focused on hitting near-term objectives, i.e., finishing 150 major projects by September 2025. Projects such as the formation of the Bharat Container Shipping Line and the creation of Coastal Green Shipping Corridors are examples of the concrete action being undertaken under MAKV 2047. With an anticipated investment of ₹80 lakh crore, the Maritime Amrit Kaal Vision 2047 has the potential to change the maritime scenario in India, promoting financial development and improving its global maritime power.

HARIT SAGAR GREEN PORT GUIDELINES:

The **Harit Sagar Green Port Guidelines 2023,** released by Indian Ministry of Ports, Shipping and Waterways, offer an organized framework for Indian ports to shift to a sustainable and environmentally conscious environment. Achieving the "Zero Carbon Emission Goal" in the marine sector and adhering to India's overall climate action plan are both made possible by the rules. The phrase "green ocean," or "Harit Sagar," emphasizes the importance of environmental sustainability in port maintenance, operation, and development. The recommendations promote a whole-of-scheme action plan addressing a few specific areas. To begin with, they make minimization of waste a top priority on the "Reduce, Reuse, Repurpose, and Recycle" strategy to achieve zero waste discharge due to port activities. Second, Harit Sagar highly recommends adopting clean and green energy forms such as creating infrastructure for dealing and bunkering emerging green fuels such as hydrogen, ammonia, and methanol. This is a straight

support for India's National Green Hydrogen Mission, which puts ports in a central position within this new sector. They also reinforce the role of open environmental reporting by calling for the implementation of the Global Green Reporting Initiative (GRI) standards. For effective implementation and to appreciate exceptional efforts, Harit Sagar implements a monitoring framework in the point of ecological Performance Indicators and the Sagar Shreshtha Samman awards to recognize ports achieving high environmental excellence. At the core, Harit Sagar Green Port Guidelines provide a strategy for Indian ports to actively decrease their environmental impacts, increase the efficiency of their resources, and develop a cleaner maritime industry. Through encouraging good practices and integrating green technologies, these guidelines are key to establishing India's ports as environmentally compliant and internationally competitive centers**.**

1.4.Objective of the Study

- To study the systematic research is to investigate, analyze, and assess green port strategies that help in ensuring sustainable port practices.

- To investigate technological advancements, regulatory measures, and managerial strategies embraced by ports globally to ensure sustainability.

- To research an integrative approach of how such strategies follow with international environmental aspirations, including the cut in GHG emissions and compliance with global standards.

- To identify the issues and opportunities of executing green strategies, presenting suggestions for port administrations, policymakers, and stakeholders towards facilitating the shift towards environmentally friendly and economically sound port operations.

1.5. Scope of the Study

- This study will examine the evolution, implementation and effectiveness of green port strategies that result in sustainable port operations. It will analyze how the dimensions are done by the following methods,

- Evaluation of measures intended to reduce pollution, emissions, and energy use

- Evaluation of smart technologies and automation solutions (e.g., IoT, AI, digital twin technology)

- Examining national, global, and municipal regulations and how they affect the adoption of sustainable practices at ports

- Examination of port authority, shipping company, government agency, and community engagement in green strategy advocacy and adoption

- Assessment of cost-benefit trade-offs, source of funding, and financing incentives for green port initiatives Guidelines of best practices and lessons learned from leading green ports worldwide.

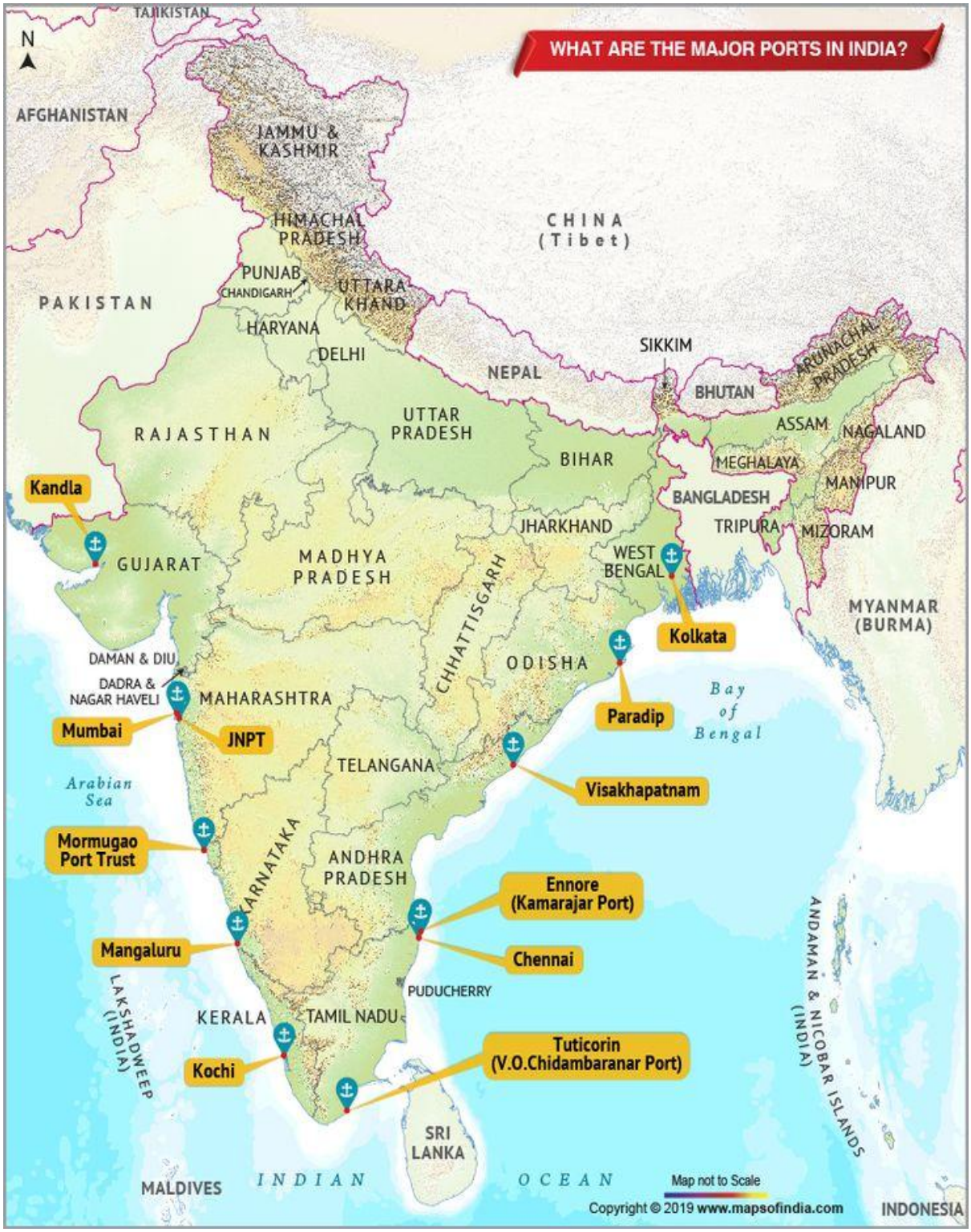


Fig.1.3 Major ports in India

Sources:https%3A%2F%2Fin.pinterest.com%2Fpin%2Fwhat-are-the-major-ports-in-india-map--

1.6. RESEARCH METHODOLOGY

This study will primarily focus on secondary data sources such as:

- Research Papers and Publications by ports and maritime researchers.
- Worldwide Carbon footprint emissions and green port measures on Economic trends.
- Credible news articles and industry reports focusing on “Waste to Wealth “and 5R Concepts.
- The limitations of Secondary data will be acknowledged and addressed through using multiple data sources.

1.7. LIMITATIONS OF THE STUDY

- Secondary data sources may have inherent biases or limitations in accuracy.
- A comprehensive knowledge of particular ports or areas in their effects on policy is limited by the lack of primary data gathering methods, such as surveys, questionnaires, or interviews with stakeholders, port authorities, and policymakers.

CHAPTER - II

LITERATURE REVIEW

2.1. Introduction to Literature Review

- An extensive and comprehensive examination of the pertinent academic work on a given topic is provided by a literature review, which is a fundamental component of every research activity. It is a thesis, detailed results, highlighting key topics, and pointing out gaps in current knowledge rather than just a collection of abstracts. A literature review lays the groundwork for a new study by carefully examining previous research to demonstrate its applicability and possible worth to the field.

- In the end, it provides a strong intellectual basis on which new knowledge may be built, avoids needless repetition, and guides methodological decisions. The development of a specific research question, a thorough search for pertinent sources, a rigorous evaluation of their quality and applicability, a meaningful analysis and synthesis of the information gathered, and, finally, a clear and logical presentation of the synthesized knowledge are all steps in this methodical process. In actuality, a well-conducted literature review is a serious assessment that may result in useful and significant research rather than just a summary of the job completed.

2.2. Literature Analysis

2.2.1. Overview of green port strategies and sustainable port operations

This paper aims to provide an intellectual model of sustainable green port practices. Ports are the entry point for global trade, and as a result, implementing Green Port Initiatives (GPIs) is the best way to highlight the importance of maintaining a safe environment for future generations. The IMO enforces this law to protect the environment and society, and ports are now interested in non-business reasons, such as environmental issues related to the ports, in order to make their operations appear sustainable. Finding out how well-informed the port community is about GPIs is the first step; mapping the port GPIs to the six main areas of Green Port Concepts is the second; knowing the first major program areas that the port community

wants to apply to is the third; and comparing Northport's GPIs to those of another port for benchmarking purposes is the fourth. The conclusion will include recommendations on how Northport (Malaysia) Berhad may best exercise and maintain its GPIs in order to continue operating and, most significantly, achieve the 17 Sustainable Development Goals of the United Nations. (**Iznoorhakmal bin Ibrahim,2023)**

This study examines the environment friendly port has emerged as today's world issue. Ports everywhere in the globe are now voluntarily planning to make our mother Earth sustainable. This paper will examine the general port planning, green port development and present activities for a green port. There exists a worldwide agreed system created by Eco Ports that motivates individual ports to voluntarily become a part of the community and commit to save the environment. At this point, it is advisable not to invent the new wheel but to embrace and then develop further the Eco Ports SDM approach and PERS certification already globally accepted as green port standard**. (Nazry bin Yahya,2019)**

This article defines the term green ports as a part of logistics chain and the transport networks are under sustainable development and process optimization. Port expansion should always be considered in the environment of environmental legislation and its perpetration in different public laws. The composition shows how living conditioning of a sustainable harborage frugality can be structured and further developed in order to establish sustainable logistics and voluntary measures or measures initiated by the stakeholders **(Dimitar Dimitrakiev, Georgi Gilev,2021)**

This chapter sets out the subject of green ports and puts in place the background and motivation for this volume. The chapter presents a broad perspective of the salient features of environmental matters in shipping, with particular focus on the port context. It is then followed by the existing, nascent and potential strategies to adopt more sustainable approaches, the various players concerned and also the significance and evolving character of national and global regulation. The book's format is established and a concise summary of every chapter is offered. Lastly, the chapter finishes with reflections on emerging trends and the port sector's future environmental performance. **(Rickard Bergqvist and Jason Monios,2019)**

2.2.2. Environmental impacts of port operations

The rising international issues like climate change and energy consumption, port operations, and environmental impacts have increased in recent years. Since it is open to a more stringent examination of regulating ecological enforcement, the port sector encounters more challenges. Most efforts towards encouraging sustainability like green ports, sustainable ports. However, current planning is still a challenge for sustainable ports and green ports in order to be successful in terms of sustainability. This thesis, based on a literature review, endeavors to provide answers to these challenges in sustainable port planning. We submit introducing environment-friendly insights on sustainability from a maritime supply chain perspective into port planning. From this standpoint, the Green Port definition is proposed. This study provides elaborate and extensive awareness of green port strategies for sustainable port planning in order to address the global environmental problems and sustainable development. **(Soukaina Sibaouaih,2021)**

This article explains the grounded on a recent study conducted by a health board, boat and seaport adulterants lead to roughly 19,000 new cases of lung cancer each time and claim the lives of around 60,000 people. Ship CO2 emigrations, on the other hand, have been adding continuously and are likely to regard for roughly 2.7 of all global emigrations. similar issues heighten the significance of addressing action to limit carbon emigrations in ports. As profitable ports have fiscal interest enterprises and should strike a balance between these profitable interests and environmental enterprises. This study sought to classify carbon footmark reduction measures at marketable ports using an Environmental Impact Assessment as a scoping review to help and streamline unborn policymaking. The findings tried to classify the conduct in a new and holistic manner to grease easier analysis of carbon footmark reduction conduct by policymakers and scientific circles in seaports. The end of the study frame, there are some recommendations for farther exploration to more develop new ways for seaport carbon reduction **(Seyed Behbood Issa Zadeh, Jose Santos Lopez Gutierrez, Maria Dolores Esteban Perez, Gonzalo Fernandez-Sanchez,2023)**

Decarbonization compromise plays an important role as an essential subject matter in all industries across the globe at present. The shipping industry is also getting its share out of this carbon-neutral trend. Ports, as one of the essential sectors in the shipping industry, are immensely influenced by this decarbonization trend. For decades, the European Sea Ports Organization has given top priority to environmental issues, sustainable development goals, and green ports. This article emphasizes giving top priority to the aspects that need to be taken into consideration among sustainable development goals and green ports, considering the European Sea Ports Organization's environmental priorities in the past five years. Consistently, a proposal of approach regarding the low-carbon energy technologies has been introduced**. (Omer Berkehan Inal,2024)**

This article defines the ports industry is essential to worldwide movement and commerce. Climate change has the potential to sabotage port activity, performing in a rise in functional shutdowns and guarantee lucrative losses. Then, we introduce an examination of literal world threat throughout the activities of 2,013 world ports and the effects under a high-end heating scenario, more offshore flooding and over beating because of ocean position increase, and the heat stress effects of cutting-edge temperatures, are the key drivers of heightened threat. ports in the Pacific islets, Caribbean Sea and Indian Ocean seem to be under very high risk by the year 2100, while African Mediterranean and the Arabian Peninsula (Red Sea and Persian Gulf) ports are expected to experience truly high risk. Pitfalls at the global level cannot quantify point position details, but these findings provide a benchmark for further investigation and decision-making. **(C. Izaguirre,2021)**

This study examines the port industry of India prospers during an external trade it becomes essential to examine the environmental effect it generates on the littoral swell. It seeks to identify the environmental goods of an arising port assiduity in India and verifies the efficacity of conduct taken to contain adding pollution due to port conditioning. Scholars have handed a relative view of green performance of large ports compared to minor ports. Experimenters have gathered primary data from 15 busiest large and minor ports of India from six different orders of stakeholders of port sector and questionnaire approach. It was observed that port operations had significant negative impacts on the terrain in the forms of water pollution, effluent disposal, dangerous poisons and so forth, experimenter has given a relative review and observed dissonances between the success rate of sustainable operations in ports. Eventually, the

experimenters have ranked the surveyed major and minor ports according to their environmental impact and performance in sustainability. **(Subhankar Das and Eliza Sharma,2020)**

The global green development has led numerous ports to put measures to reduce emigrations and better harborage effectiveness. As large- scale construction can do damage to the terrain, it isn't supported under the green strategy, While whether there's a relationship between emigrations and harborage effectiveness. To break the two problems, this paper takes the case of Shanghai Port and Busan Port, and uses the three- stage DEA to estimate the effectiveness of the two ports independently. Pollutant emigrations from the ports are named as an environmental variable in the alternate stage to examine their goods on the redundancy of input variables. The results indicate that the effectiveness of Shanghai Port is inadequate due to inordinate scale and contaminant emissions. **(Xiaoling HUANG,2019)**

This study investigates the influence of port operations that lead to a decline in environmental quality in recent years. Despite the challenges posed by the deteriorating quality of the terrain, ports throughout the world must continue to function and do their duty in order to provide global trade services. As a result, the government and a number of ports have started to create green ports. The term "green port" refers to a port concept where ecologically friendly activities are conducted. This journal aims to illustrate the evolution of the green port and the challenges that exist in the Tanjung Priok port. One of these innovations is the reduction of boat energy emigrations and the management of boat harmful waste. **(Juan Kersasyudha Prasetya,2019)**

Ports and harbours are in fierce rivalry for customers and provide safer, more effective global shipping for commodities. In order to better handle the increasing difficulties of having safe, secure, and energy-efficient facilities with smaller environmental footprints, efficient ports are using sophisticated technology. In order to do this, a well-known idea that has gained popularity is the smart port. The goal of this study is to develop a smart port paradigm and a quantitative metric called the smart port index (SPI) that will allow ports to monitor and enhance port sustainability. Critical performance indicators (KPIs) rooted on literature documentation served as the foundation for our SPI methodology. The four main activity areas of a smart port—operations, environment, energy, and safety & security—formed the framework of these KPIs. To demonstrate how to apply SPI and assess the performance of some of the busiest ports in the world, case studies are carried out. In order to continue continual development, our

approach gives port authorities a quantitative model to create smart port plans, assess their intelligence, and identify the advantages and disadvantages of their existing operations. The study's findings also imply that regionally specific elements and the policy framework may have an impact on SPI value. **(Anahita Molavi,2019)**

This article describes the two environmental issues that ports face: the effects of maritime transport on the environment and the products of maritime transport on the land (such as pollution and CO2 emigrations). The summary of the primary obstacles encountered in proactively engaging ports, providing price schemes or green instruments to complying boats, and identifying key indicators for tracking GHG emigrations is provided in Chapter 6. In addition to lowering the sulphur cap in energy oil painting for vessels from 3.50 percent to 0.50 percent, the IMO 2020 regulation aims to add the EU's hothouse gas emigration and create the most ambitious package of measures, along with an original roadmap of crucial programs in cutting-edge exploration and invention, in green technologies, and in sustainable results for the decarbonization of European ports and the sustainable development of their crucial rudiments. It is expected to have an original roadmap of crucial programs in cutting-edge exploration and invention. (**Vera Alexandropoulou,2020)**

This study explains there are growing concerns regarding the environmental footprint of port development and operations because of urgent global challenges like climatic change and energy efficiency. One of the key drivers for sustainability is to acquire and retain customers who care about sustainability. Therefore, creating a green port marketing plan achieving the economic, social, and environmental goals will direct a port towards development of sustainability. The present research is trying to examine the world's biggest ports green marketing position. According to the theories of green marketing, the green marketing position of these ports is reflected in their structure, form, and functions. The findings indicate that over half of the 30 cases are actively pursuing green marketing. However, ports taken more towards strategies, and lesser towards structures and functions. Port authorities are suggested to link the three key ingredients in green marketing initiatives**. (Jasmine Siu Lee Lam,2019)**

2.2.3. Green port initiatives and best practices

Port Infrastructure & Trade must be continually developed in order to accelerate the expansion of the industrial sector and realize the Make in India ambition. India's impressive competitive advantage is its 7,517-kilometer coastline. India has over 200 smaller ports and 12 larger ports

spread out throughout this stretch. There are several opportunities to grow the marine industry. The government recommends the Sagar Mala Program and plans to connect the ports along the peninsular strip's coastline in order to support the local potential and increase the physical marine commerce opportunities. in order to facilitate the easy and speedy transportation of goods from the industrial locations to the containers, as well as the establishment of road and railway lines that keep up with the ports. Initiating the technological infrastructure requirements, green energy generation, and environmental management systems, the current article attempts to highlight the Green Port program and Green Port strategy of New Mangalore Port. All of these solutions will improve the minor ports' capacity, which will ultimately result in the massive increase of 275–325 MT that is expected to occur soon. **(SB Venkatesh and Dr. V. P. Sriraman,2020)**

With increasingly fast-changing technological advancements triggered by the Fourth Industrial Revolution (Industry 4.0), modern seaports are under pressure to alter their operational mode to manage traffic flows. As such, an adjustment necessitates the creation of a new smart port system. In order to enable port communities to better understand concepts of smart ports and effectively establish a smart port in a global supply chain, this paper synthesizes essential concepts of smart ports, designs supporting architecture, and suggests particular milestones for tracking the smart port development project. We employ and to point out key success factors (e.g., fundamental components for the smart port architecture, value propositions, smart port performance indicators) for the establishment and development of smart ports. Our studies find that a smart port lessens port-user response time, optimizes port asset utilization, and maximizes maritime logistics visibility through automated and end-to-end digital integration of port operations without direct human intervention**. (Hokey Min,2022)**

Green development is the unborn development direction of the ports and the foundation of green ports construction is the operation of new technology. This paper introduces the crucial technology (operation of high voltage reinforcement power, large scale operation of RTG oil painting to electricity, operation of intelligent and precise dust repression technology in coal terminal) operations of several types of green ports development, and provides suggestions for the unborn port establishment. **(Xu Guo,2021)**

This paper examines and classifies ports' green initiatives aimed at lowering their polluting emissions and enhancing their overall environmental performance. By way of systematic review that integrates both academic and industry literature, green port practices such as strategies, tools, infrastructures, and initiatives were established. A total of 380 records of green practices that have been investigated by ports and port stakeholders across the world have been examined. The key aspects of the practices, features, challenges in implementation, and indicative environmental impacts are identified. The findings indicate that the most frequently debated green solutions are activated by the consideration of needs and interest of the ports to create environmentally sustainable operations, while simultaneously competing on a sustainability basis within the port industry. Therefore, the most heavily researched solutions comprise (i) Shore Side Electricity–Onshore Power Supply, (ii) alternative fuels, (iii) circular economy, and (iv) waste management. **(Konstantia Karagkouni,2024)**

With a focus on stakeholders' opinions, participation, difficulties, and recommendations for ecologically friendly port operations, this study examines green port projects in India. 16 respondents from a variety of backgrounds—including port officials, academics, freight carriers, port developers, operators, shipping lines, businesspeople, and environmentalists—were interviewed for auto schematics. To identify important themes and patterns, data collected through in-person and online interviews was subjected to qualitative content analysis. The results show that respondents are generally satisfied with current initiatives and are aware of green port concepts and sustainable practices. By offering helpful guidance and highlighting important elements for guaranteeing sustainable port operations in India, this study advances existing information. Policymakers must develop economic incentives and green port policies that are both practical and efficient. **(Dr. RUPESH KUMAR,2025)**

This study explains seaports and cities are internally linked, and the ports can have a strong influence on the megacity, especially in the environmental aspect. Port authorities are seeking for greener forms of ports operation to adopt the state policy and to increase their profitable and environmental competitiveness. The preface of the conception of sustainable development in the ports can stimulate the creation of green cities. This paper uses a case study to dissect the sustainable development in the Twin Port of Bremen. It's shown that the ports development stimulates GDP growth, increases employment, civic structure development, and the overall

enrichment of harborage cities. Using the presented analysis of the green ports, the most important affecting factors are proposed. **(Adriana Bohdan,2022)**

Green ports or eco-ports, focus on social, economic, and environmental dimensions in their operations and management, above simple business gains. The purpose of this study is to follow up research publications regarding green ports throughout history and find out knowledge trends and future themes with bibliometric analysis. With 462 articles from 1991-2023 published on Scopus, the study discovers three stages of green port studies: initial stagnation (1991-2006), infant growth (2007-2015), and expansion (2016-2022). This is the reason that country China has numerous container ports as the top 10 biggest container ports worldwide with a collective market share of up to 70% of the world. Based on this analysis, it is seen that the knowledge map and direction of future topics in the case of green ports are "sustainable development", "port development", "port operation", "carbon emissions" and "renewable energy resources" apart from that also seen that there exists a direction of the current green port and "smart port" research trends. Therefore, the research themes required are alternative strategies in net zero emission (NZE) in ports in the operational and development dimensions of the port. **(Nurdin Ahmadi, Sri Rahardjo, Sinta Hasriningtyas,2023)**

2.2.4. Theoretical frameworks and models for sustainable port operations

Because a large portion of international trade is conducted through the maritime sector, seaports are important players in global economies. The economic significance of seaports is demonstrated by the numerous positive effects they have on the communities in which they are located. The goal of this paper is to examine the potential for achieving sustainable development of seaports through the development and implementation of innovations and technology. The study's findings indicate that innovations in the maritime industry are primarily directed towards the current markets and have a discounted process of minor increments in vessel design and construction, fuel technology, and port infrastructure. However, the potential for seaport development can also be through ICT-oriented innovations that can address economic, environmental, and social problems. Innovations can address social, environmental, and economic problems and offer substitute principles for achieving seaports' sustainable growth. **(GORANA MUDRONJA,2022)**

As global marine trade keeps expanding, there is an increasing demand for sustainable performance that is socially conscious, ecologically benign, and commercially feasible. Therefore, to ensure feasible plans to achieve sustainable development objectives, all stakeholders must engage in open evaluation, enhance governance and scientific collaboration, and build inclusive communication. In order to identify the difficulties and potential solutions for developing a sustainable port, this case study goes into great detail on a Mediterranean seaport. In order to maximize sustainable multi-objective design criteria, the goal is to provide a method that will assist policymakers in creating future plans. The link between a number of factors pertaining to particular demographics was then examined using software from the Statistical Package for Social Sciences (SPSS). In order to reduce the variables without significantly sacrificing information, factor analysis was employed. In order to maximize environmental (i.e., new tools for pollution reduction/elimination recycling), social (i.e., motivation of social participation), and economic (i.e., willingness to pay) sustainability, policymakers can use the method's quantitative and qualitative tools to develop their future strategy. Road condition, traffic, and waste disposal received low ratings among the respondents, while renewable energy resources, atmospheric quality, noise, and dust received high ratings. **(Ioannis Argyriou,2022)**

This paper examines approximately 85% of international commodity trade is performed by merchant ships and marine trade ports are the most critical components of the global logistics, supply and transport chain. During the last decade, green port strategy, which are becoming common in Turkey, particularly in European ports, are directed towards spreading eco-friendly technologies, reduce the environmental impacts of port and to logistics operations and merchant trade. The implementation for Turkish ports by a comparison of the condition in the EU and in Turkey to identify and an assessment on contributions of current green eco port implementations to logistics operations and merchant trade has been conducted, and some suggestions have been stated in consequence. **(Fatih Yılmaz,2019)**

In recent times, the use of renewable energy sources (RES) in power distribution systems is adding significantly. This technology has many benefits, including energy sustainability and trustability, low- cost energy sources, and environmentally friendly. The use of RES in maritime systems like harborage micro grids greatly enhances energy effectiveness and

minimize the use of fossil energies, which poses a severe trouble to the terrain. The schematic plan to ameliorate the energy effectiveness of contemporary ports, similar as ports micro grids and seaport smart micro grids are handed. Incipiently, the operations of arising technologies in seaports are handed. indicator TERMS Digitalization, energy effectiveness, Internet of effects, smart energy operation, harborage micro grids, green/smart port**s**. **(MUHAMMAD SADIQ,2021)**

The research sought to establish the significance of each dimension and sub-dimension of a digital port, in the interest of sequencing them to attain a view regarding the digital solutions to be undertaken in Romanian river-sea ports. The significance of each dimension/sub-dimension was established based on the AHP (Analytical Hierarchy Process) approach. The findings indicated that port operations are the most critical, followed by the environment, safety and security, energy, and employees training. The ordering of the dimensions/sub-dimensions typical of the ports under examination enabled identifying the digital solutions beneficial for the technological changes and management practices required to digitize **(Carmen GASPAROTTI,2023)**

This article explains the ports and harborage cities play a vital part toward the sustainable development of littoral ecosystems. These ecosystems give their natural capital by offering favorable locales for assiduity and availability to world requests. Around the world, harborage authorities are aligning their intentions toward their donation to the sustainable development pretensions (SDGs), similar as the World Port Sustainability Program (WPSP) for harborage authorities and AIVP 2030 for port cities. The chapter end is to assess to what extent ports have contributed to the execution of SDGs. The analysis is grounded on a content analysis on a portfolio of 212 systems in which harborage authorities demonstrate leadership in sustainable development. Port authorities also have “do good” intentions for their ecosystems, which are substantially concentrated on readministering connections with communities and lower to restore their impact on the biosphere. likewise, the findings between WPSP systems with the SDGs are rather nebulous. Directions are given toward a methodology for harborage authorities (papas) to establish a stronger link between(monitoring) business strategies with the perpetration of inclusive harborage development strategies to help using SDG reporting for greenwashing purposes. **(Maurice Jansen, 2023)**

This article describes the MAGPIE concept for the Horizon 2020 Green Deal, which began in October 2021 and uses a living lab approach to demonstrate outcomes for multimodal, smart, and green integrated transport. Results include digital, non-technological, and green energy carriers for shipment by truck, rail, inland raceway, and marine to, from, and inside ports. The trials will take place in the harbor region of Rotterdam, and their potential for expansion to other harbors will be evaluated. Every MAGPIE development will culminate in a master plan that includes a roadmap for smart and environmentally friendly anchorages. MAGPIE will collaborate with key players in logistics and transportation to evaluate the potential for exploitation and make sure that design concerns are addressed. The design plans and innovative innovations are discussed in this study. **(Maarten Flikkema,2023)**

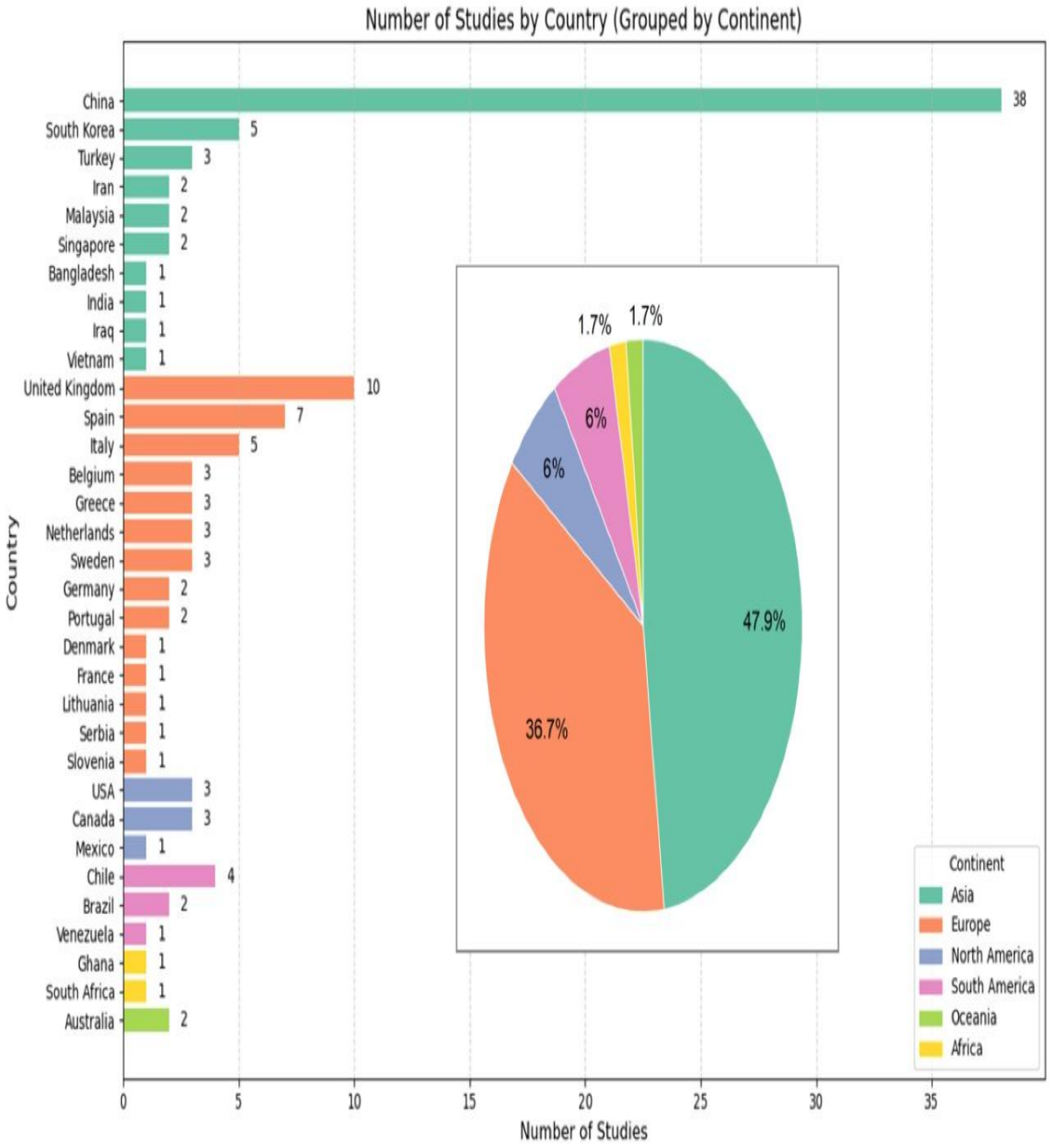


Fig.2.1 No of Studies by country (Continent) (As on 2023)

Sources: www.mdpi.com%2F-

CHAPTER - III

GREEN PORT STRATEGIES

3.1. Overview of sustainable port operations

Green port strategies form a critical element of sustainable maritime development, working to reduce the atmospheric impact of port activities without compromising economic progress and social obligation. With rising global trade, ports are expected to cut down on emissions, increase energy efficiency, and be environmentally friendly. Green port strategies include a broad field of technology, operational, and policy initiatives to achieve this.

1. Energy Efficiency and Renewable Energy

Improving port operations' energy efficiency is a crucial component of green port development. In order to generate electricity, ports also make investments in renewable energy sources like wind and solar. Energy storage and on-site generation technologies also reduce greenhouse gas emissions by using less fossil fuels**.**

2. Shore Power (Cold Ironing)

Cold ironing, often known as shore power, is one of the best strategies. By doing this, ships may cut off their diesel engines and significantly reduce air pollution by connecting to a port's electrical supply while in port. Particularly efficiently, shore power lowers emissions of nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter (PM), all of which are detrimental to the environment and human health**.**

3. Waste Management and Pollution Control

Green ports utilize holistic waste management strategies to manage solid waste, hazardous substances, and ballast water from vessels. These measures encompass recycling, treatment of sewage and oily waste, and the application of eco-friendly antifouling paints. Containment mechanisms and emergency response strategies are also essential in avoiding and containing accidental spills.

4. Sustainable Infrastructure and Design

Ports are now embracing sustainable design principles in new developments. This involves recycled materials for construction, energy-efficient buildings, and incorporating green areas. Eco-engineering strategies such as the provision of wetlands or coastal natural buffers improve biodiversity and provide a barrier against coastal erosion and flooding.

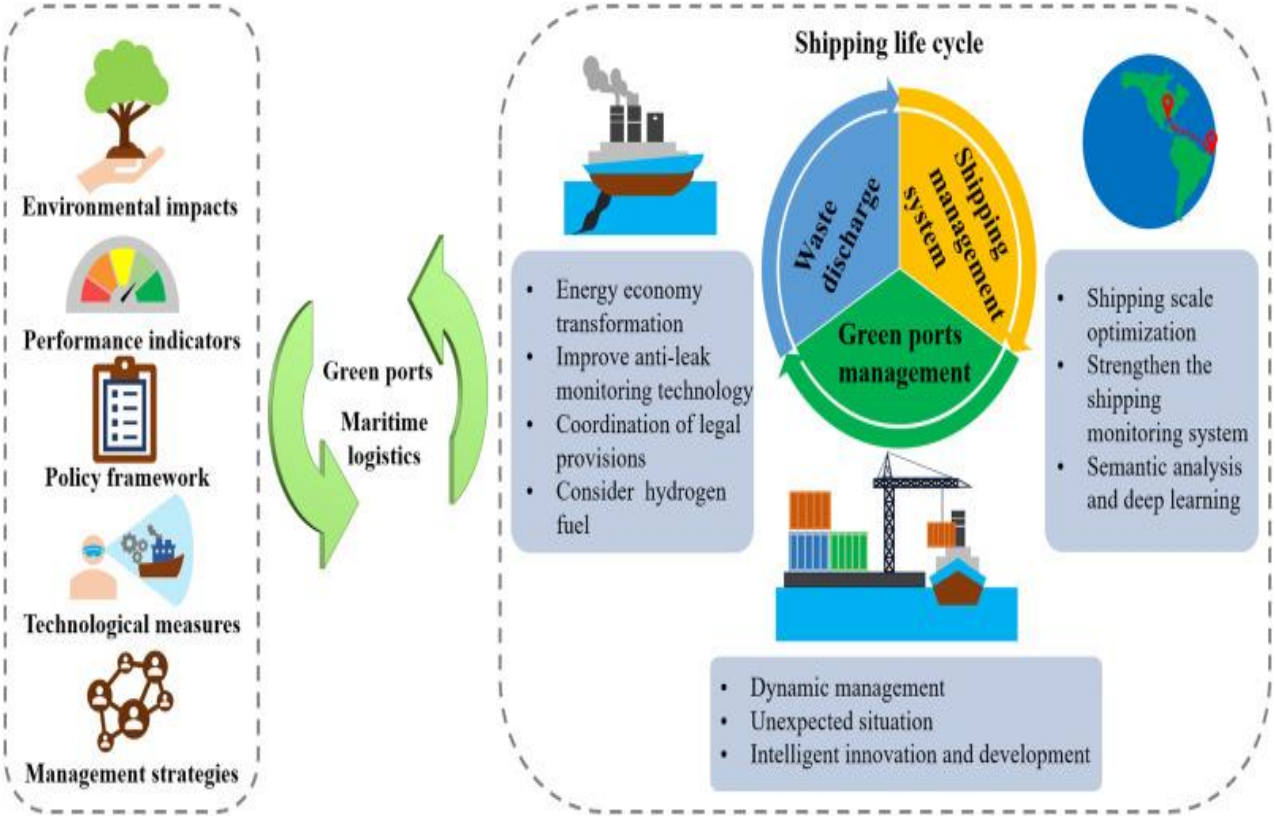
5. Digitalization and Smart Port Technologies

The adoption of digital technologies improves environmental performance and operational efficiency. Intelligent port systems employ IoT (Internet of Things), AI (Artificial Intelligence), and big data analytics to track emissions, optimize traffic, and handle logistics. These technologies are responsible for less fuel consumption and reduced idling hours, also decreasing the carbon footprint.

6. Stakeholder Engagement and Regulatory Compliance

An effective green port policy depends on cooperation among stakeholders such as port authorities, shipping lines, local communities, and government authorities. Open reporting, environmental certification schemes (e.g., ISO 14001), and public involvement are essential to ensure accountability and community support.

Fig 3.1 Shipping life Cycle .



Sources:www.sciencedirect.com%2Fscience%2Farticle%2Fpii%2FS0048969723077057

3.2. Analysis of green port initiatives and their effectiveness

An international trend in the marine industry, green port initiatives aim to mitigate the environmental impacts of port operations and related activities. Green port projects encompass a wide range of strategies aimed at reducing energy consumption, promoting the use of renewable energy sources, improving waste management, and lowering air and water pollution.

Effectiveness:

The effectiveness of green port initiatives can be increasingly discerned through the numerous successful applications across the world. Ports that have implemented these programs typically claim significant reductions in greenhouse gas emissions, better water and air for the local population, and improved cost and energy efficiency. For example, the deployment of shore power enables ships to plug into the port's electrical system while docked, which reduces auxiliary engine emissions dramatically. In the same way, the shift to electric or hybrid-powered port machinery such as cranes and vehicles greatly reduces the carbon footprint. By following and sometimes surpassing environmental regulations, such ports improve their image, draw eco-friendly businesses, and place themselves in a good position for future environmental policy and market requirements. Certifications such as ISO 14001 also assist in showing their dedication to sustainability and gaining stakeholders' trust.

3.3. Case studies of successful green port implementations

- **Port of Rotterdam, Netherlands**

Rotterdam, being the biggest port in Europe, has embraced bold sustainability plans. It makes use of shore power facilities to lower dockside ship emissions and has made significant investments in clean energy ventures such as wind farms and solar farms inside the port. It also encourages LNG usage as a cleaner fuel at sea and is planning to set up hydrogen infrastructure for zero-emission shipping.

- **Port of Los Angeles, USA**

Port of Los Angeles has led the "Clean Air Action Plan" (CAAP) since 2006, in cooperation with the Port of Long Beach. The plan involves tight emission controls, electric cargo-handling equipment, and shore power for ships. These initiatives lowered diesel particulate matter emissions by more than 80%. The port is also testing zero-emission trucks and terminal automation.

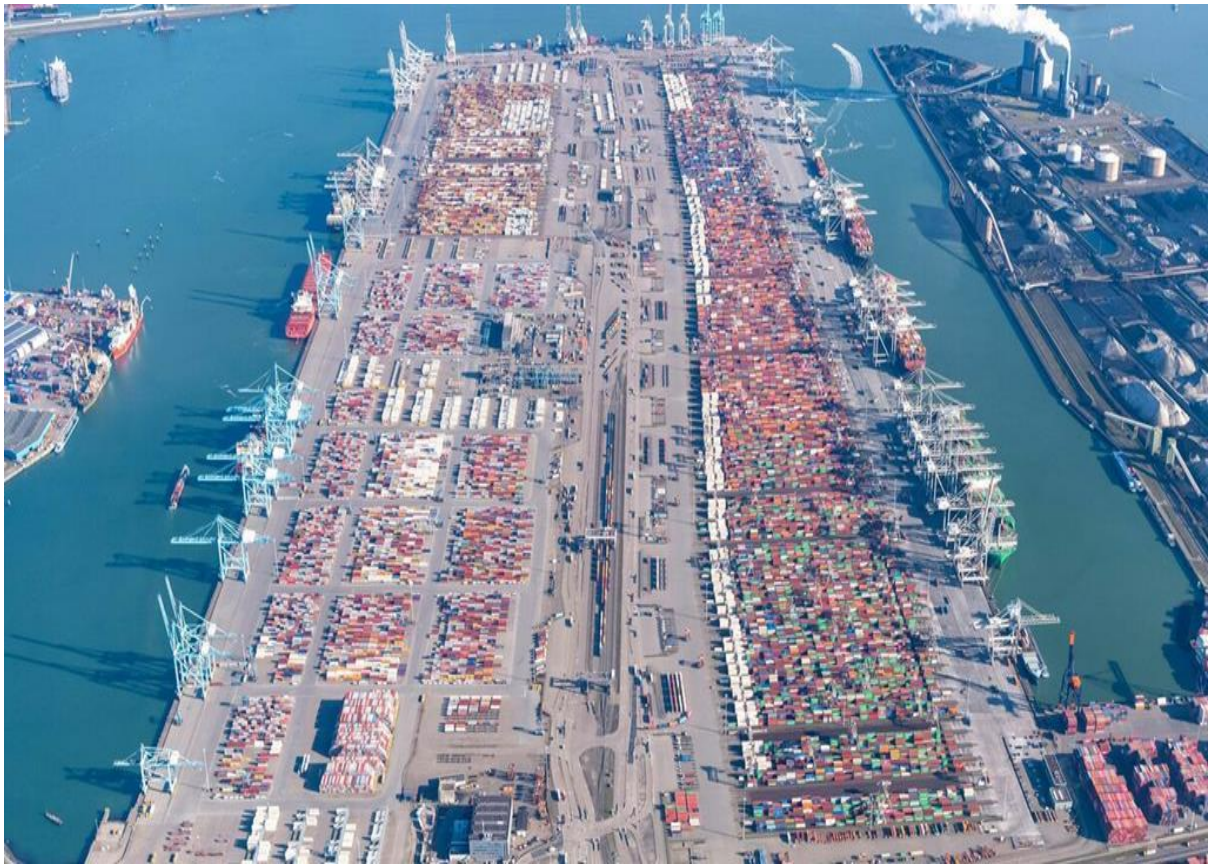
- **Port of Gothenburg, Sweden**

Port of Gothenburg is Scandinavia's green innovation leader. It provides discounts on port charges for low-emission ships and has large onshore power supply facilities. It encourages intermodal transport to save the road network and offers assistance to develop biofuel for shipping.

- **Port of Singapore**

Singapore has incorporated green technology into port operations in its Maritime Green Port Program. It rewards ships that utilize cleaner fuels and cleaner engines. The new Tuas Mega Port is planned with smart and energy-saving systems, such as automated cranes and environmentally friendly building designs.

These case studies approaches involving technology, policy, and stakeholder participation are important for initiating effective green port initiatives and shifting the maritime industry toward environmental sustainability.



Sources:https://www.rotterdammaritimecapital.com/industry/port-logistics

Fig 3.2. Port of Rotterdam

CHAPTER – IV

SUSTAINABLE PORT OPERATIONS

4.1. Overview of sustainable port operations

Sustainable port operations seek to reconsider economic development with environmental and social sustainability. This means reducing the adverse effects of port operations while increasing their benefits to stakeholders and future generations. Ports are essential gateways for international trade, and their sustainability is essential for a robust and environmentally friendly supply chain.

Major Elements of Sustainable Port Operations:

Environmental Sustainability: This uses a number of strategies to reduce the port's environmental impact.

Emissions Reduction: Switching to cleaner fuels for ships and port equipment (e.g., LNG, hydrogen, electricity), using shore power for berthed ships, and streamlining traffic flow to reduce fuel usage.

Waste Management: Adopting the "reduce, reuse, recycle" philosophy, enhancing waste segregation, and pursuing circular economy projects to recycle waste materials.

Water Quality: Installing high-tech wastewater treatment facilities, regulating ballast water discharge, and avoiding spills of oil and hazardous materials.

Noise Abatement: Taking action to lessen ship and port noise pollution, especially in the vicinity of residential areas and marine environments

Protection of Biodiversity: Minimizing the impact of land fill and spattering on marine ecosystems, creating parks and green areas near ports, and taking action to stop invasive species from being introduced.

Economic Viability: Making the port sustainable in the long term and competitive in its operations and pricing, while also assisting in regional and national economic growth.

Innovation and Technology: Implementing digital technologies, automation, and smart logistics solutions to enhance efficiency and minimize environmental footprint.

Social Sustainability: Managing the social effects of port activities and providing a secure, healthy, and equitable working and living environment for employees and local populations.

Safety and Health: Ensuring high levels of safety and training to avoid accidents and occupational risks.

Community Engagement: Consulting with local populations to resolve issues, reduce negative effects (e.g., noise, traffic), and enhance benefits (e.g., job generation, economic opportunities).

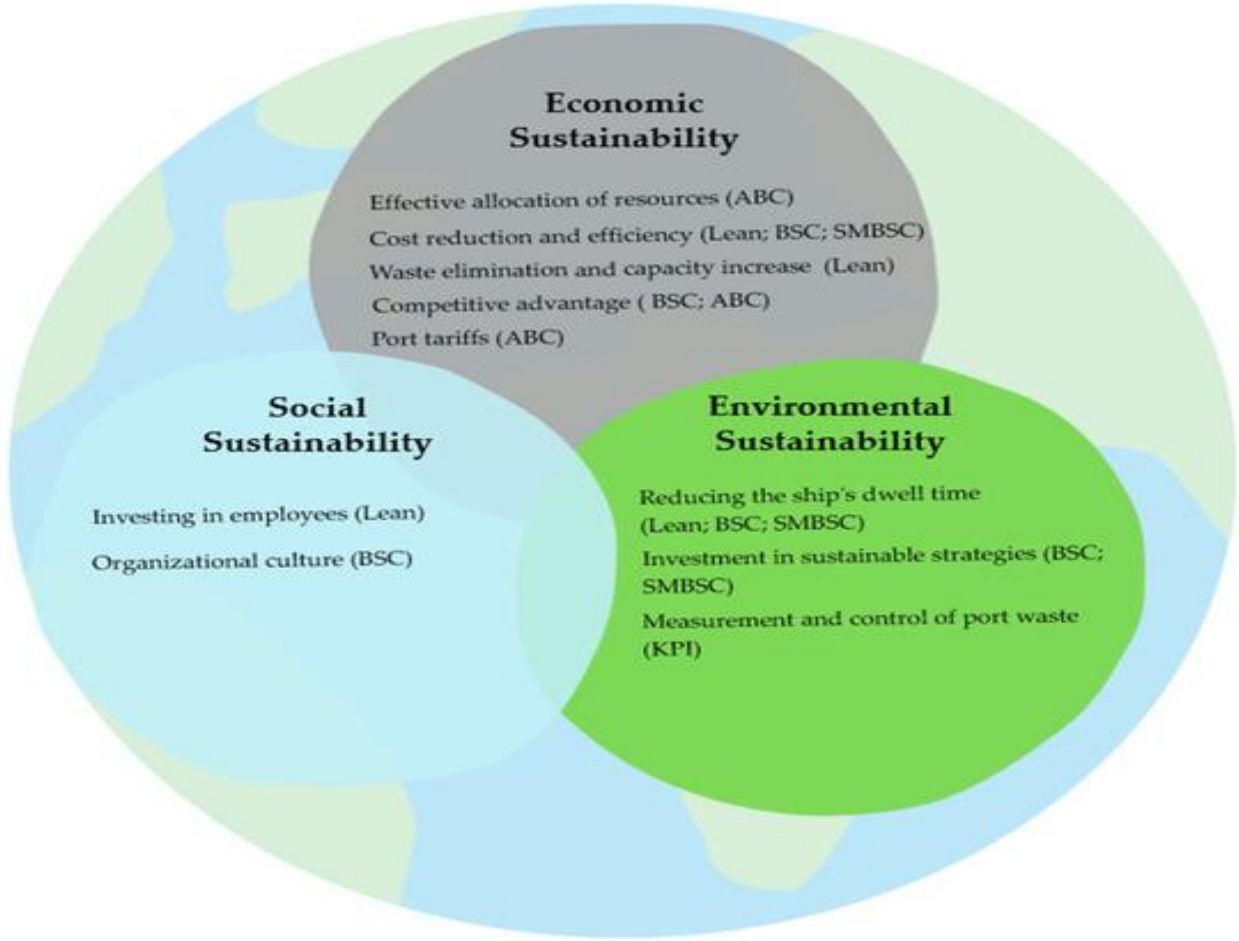


Fig4.1 Types of Sustainability

Sources:www.google.com/url?sa=i&url=https%3A%2F%2Fwww.mdpi.com%2F2071-

4.2. Analysis of sustainable port operations practices and their benefits

Sustainable port operations refer to environmentally responsible practices aimed at minimizing the ecological footprint of maritime transport while maintaining economic efficiency and social responsibility. These operations involve integrated strategies to reduce emissions, manage waste, conserve energy, and protect marine ecosystems.

Using shore electricity, also referred to as cold ironing, is a crucial technique that enables ships to connect to the home docking electric grid, lowering the need for onboard diesel generators and lowering air pollutants including nitrogen oxides (NOx) and sulphur oxides (SOx). In order to reduce carbon emissions and their dependency on fossil fuels, ports are also investing in renewable energy sources like wind and solar to power their operations. Energy-efficient structures, electric cars, and intelligent logistics systems are examples of green port infrastructure that enhances operational effectiveness and resource management. To preserve marine biodiversity, port authorities also enforce stringent ballast water and oil spill management procedures, as well as garbage reduction and recycling initiatives. Automation and digitalization improve sustainability even further by minimizing fuel usage, cutting down on idle time, and simplifying freight handling.

The benefits of these sustainable practices are multifaceted. Environmentally, they lead to cleaner air and water, reduced greenhouse gas emissions, and healthier marine ecosystems. Economically, ports can achieve long-term cost savings through energy efficiency and improved logistics. Sustainable operations also attract environmentally conscious clients and enhance competitiveness in the global market. Socially, these practices improve health outcomes for nearby communities and create green jobs, promoting overall well-being**.**

Fig 4.2. Port Sustainability Plam

Sources:www.docksthefuture.eu-the-future-dtf-defining-the-concept-of-the-sustainable-future-ports

4.3. case studies of successful green port implementations

Challenges:

- **Initial capital-intensive**: Switchover to cleaner technologies such as electric machinery, green energy technologies, and sophisticated waste management technologies can be extremely capital-intensive in the beginning.
- **Infrastructure restrictions**: Current port infrastructure might not be suitable for use with new green technologies, and modifications or upgrades will be expensive. For instance, lack of sufficient dock space or old equipment can block effective operations.
- **Regulatory complexities**: Working with changing and different environmental regulations at local, national, and global levels is time-consuming and challenging. The lack of a clear port sustainability framework may also be a barrier.
- **Stakeholder alignment**: Getting stakeholders with different backgrounds, such as port authorities, terminal operators, shipping lines, hinterland transporters, labor unions, and local communities, to agree and cooperate is vital but challenging.

- **Technological immaturity and uptake**: Despite the availability of many green technologies, some may still be in their early phases of development or may not be widely used in the port sector. Additionally, there may not be much progress in the adoption of technology.
- **Financial sustainability issues**: Certain stakeholders might view sustainability projects as expensive ventures without short-term monetary benefits. It might also be difficult to obtain grants and green startup money.
- **Climate change impacts**: Ports are growing more susceptible to climate change and extreme weather events, including sea level rise, necessitating investments in resilient infrastructure and adaptation.

Opportunities:

- **Lowered cost of operations**: Long-term cost savings can be achieved through sustainable solutions like energy efficiency and the usage of renewable energy.
- **Improved environmental performance**: Green technologies and practices are directly implemented to lower air and water pollution, carbon emissions, noise, and waste generation, resulting in a cleaner environment.
- **Increased resource efficiency**: The goal of sustainable operations is to use resources as efficiently and wasteless as possible.
- **Improved stakeholder relationships**: Interaction with local communities and resolution of their environmental issues can enhance trust and the port's social license to operate.
- **Improved competitiveness and market position**: Becoming a "green port" can increase a port's standing, appeal to environmentally aware clients, and be a source of competitive advantage.
- **Enhanced port-city relations**: Mitigating environmental issues can result in an enhanced integration of the port and its surrounding city.
- **Support of global sustainability**: Green ports are central to attaining larger sustainability objectives and helping create a more environmentally friendly world supply chain.
- **Emergence of new business opportunities**: Ports may function as centers of green energy production (e.g., hydrogen and biofuels) and bunkering facilities for substitute fuels, generating new source income.

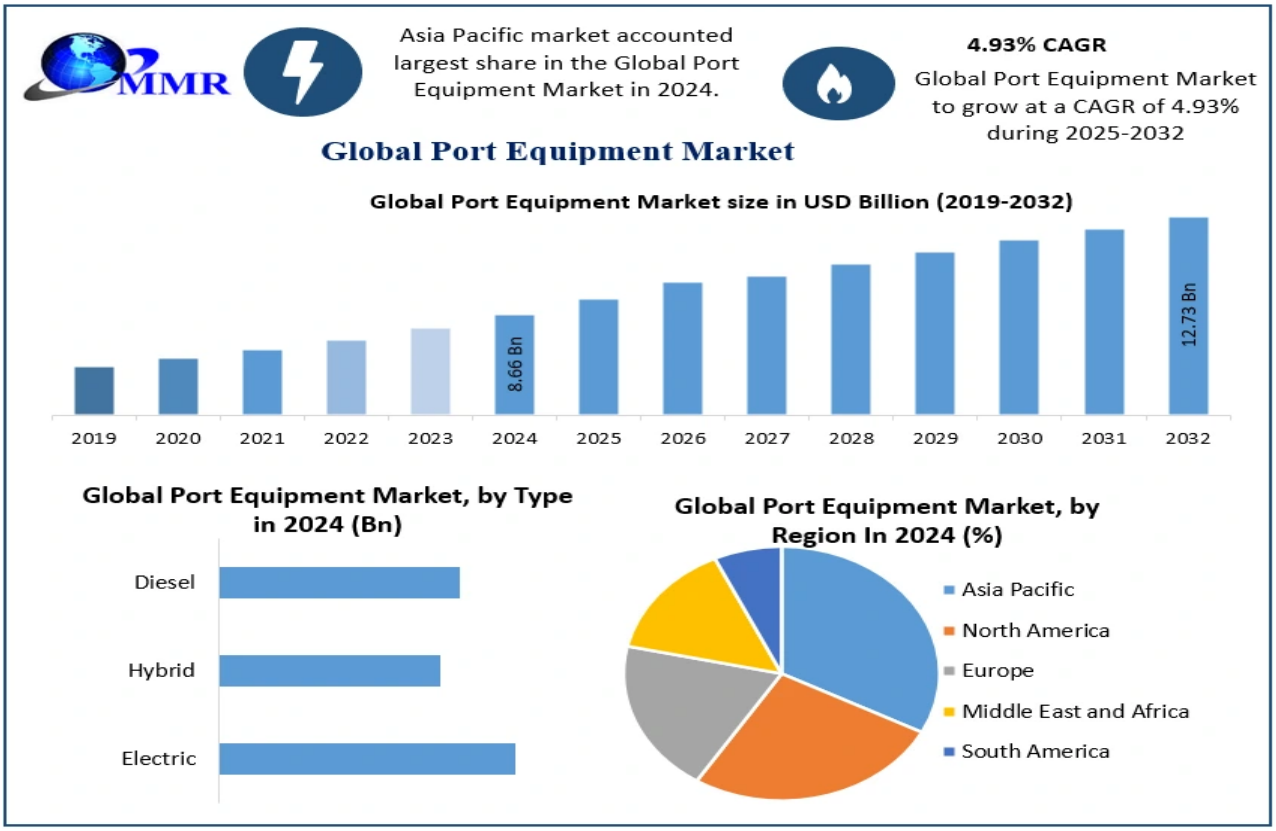


Fig 4.3. Global Port Equipment Market

sources: www.grandviewresearch.com%2Findustry-analysis%2Fport-equipment-market-report

CHAPTER - V
ANALYSIS AND DISCUSSIONS

5.1. Analysis of data collected

Overall strategy of top 30 in the world

Overall port strategy	Port, Country	Overall port strategy
1	Shanghai, China	Leading global hub port
2	Singapore, Singapore	Premier global hub port
3	Shenzhen, China	Global Container hub port
4	Ningbo-Zhoushan, China	Global Container hub port
5	Hong Kong, China	Major maritime services hub
6	Busan, South Korea	Global hub port
7	Guangzhou, China	Global hub port
8	Qingdao, China	Global hub port
9	Jebel Ali, Dubai, United Arab Emirates	To be a world trade leader
10	Tianjin, China	Global hub port

11	Rotterdam, Netherlands	A logistics hub and world-class industrial complex
12	Port Klang, Malaysia	Preferred Logistics Hub for The Asian Region
13	Kaohsiung, Taiwan	Container transshipment hub port and comprehensive value-added
14	Antwerp, Belgium	A Home port as a lever for a sustainable future.
15	Dalian, China	International shipping center and international logistics center
16	Xiamen, China	International shipping center, International transshipment hub Preferred port
17	Hamburg, Germany	Maintain and extend the position as Germany's leading transshipment hub
18	Tanjung Pelepas, Malaysia	Preferred port
19	Los Angeles, U.S.A.	The premier gateway for international commerce, a international model for ecofriendly, safety, and social responsibility
20	Long Beach, U.S.A	An international gateway for the reliable, efficient and sustainable movement of goods
21	Saigon Port, Vietnam	N/A (the port has been re-structured. Currently, operation is very N/A limited)
22	Laem Chabang, Thailand	Multimodal Transport and Logistics Center of ASEAN

23	New York-New Jersey, USA	Facilitating the efficient movement of people and goods through the region
24	Bremen/Bremerhaven, Germany	Amongst the most important universal ports in Europe
25	Jeddah, Saudi Arabia	Being the country's main commercial port
26	Tanjung Priok, Jakarta, Indonesia	Indonesia's gateway to the world's trade
27	Saigon New Port, Vietnam	A Leading container port in Vietnam
28	Valencia, Spain	Exploitation of the port's capacity as a mixed hub, optimizing port call costs and volume/mix of local import-export
29	Algeciras, Spain	To consolidate as an intercontinental logistics staging platform and hub port that is an intermodal benchmark in the Mediterranean premier container port of South Asia
30	Jawaharlal Nehru Port, India	The premier container port of South Asia

Table5.1**. overall strategy of top 30 port in the world**

.Sources: www.sciencedirect.com/science

Top Container Ports with More than 5 Million TEUs/Year

Nos.	Port	Country	TEUs
1	Shanghai	China	43.21
2	Singapore	Singapore	36.31
3	Ningbo-Zhoushan	China	27.65
4	Shenzhen	China	26.81
5	Guangzhou Harbor	China	22.57
6	Busan	South Korea	21.69
7	Qingdao	China	23.71
8	Hong Kong, S.A.R.	China	18.88
9	Tianjin	China	17.40
10	Rotterdam	The Netherlands	14.54
11	Jebel Ali, Dubai	United Arab Emirates	14.33
12	Port Klang	Malaysia	13.22
13	Antwerp	Belgium	11.34
14	Xiamen	China	10.90
15	Kaohsiung, Taiwan	China	10.12
16	Los Angeles	U.S.A.	9.61
17	Tanjung Pelepas	Malaysia	9.50
18	Hamburg	Germany	8.90
19	Long Beach	U.S.A.	8.15

20	Keihin Ports	Japan	8.01
21	Dalian	China	7.98
22	Laem Chabang	Thailand	7.97
23	New York–New Jersey	U.S.A.	7.58
24	Suzhou	China	7.20
25	Ho Chi Minh City	Vietnam	7.10
26	Colombo	Sri Lanka	6.88
27	Tanjung Priok, Jakarta	Indonesia	6.80
28	Yingkou	China	6.83
29	Valencia	Spain	5.49
30	Piraeus	Greece	5.10

Table5.2. Top Container Ports with More than 5 Million TEUs/Year

Sources: https://www.worldshipping.org/

PORT RANKINGS (2024)

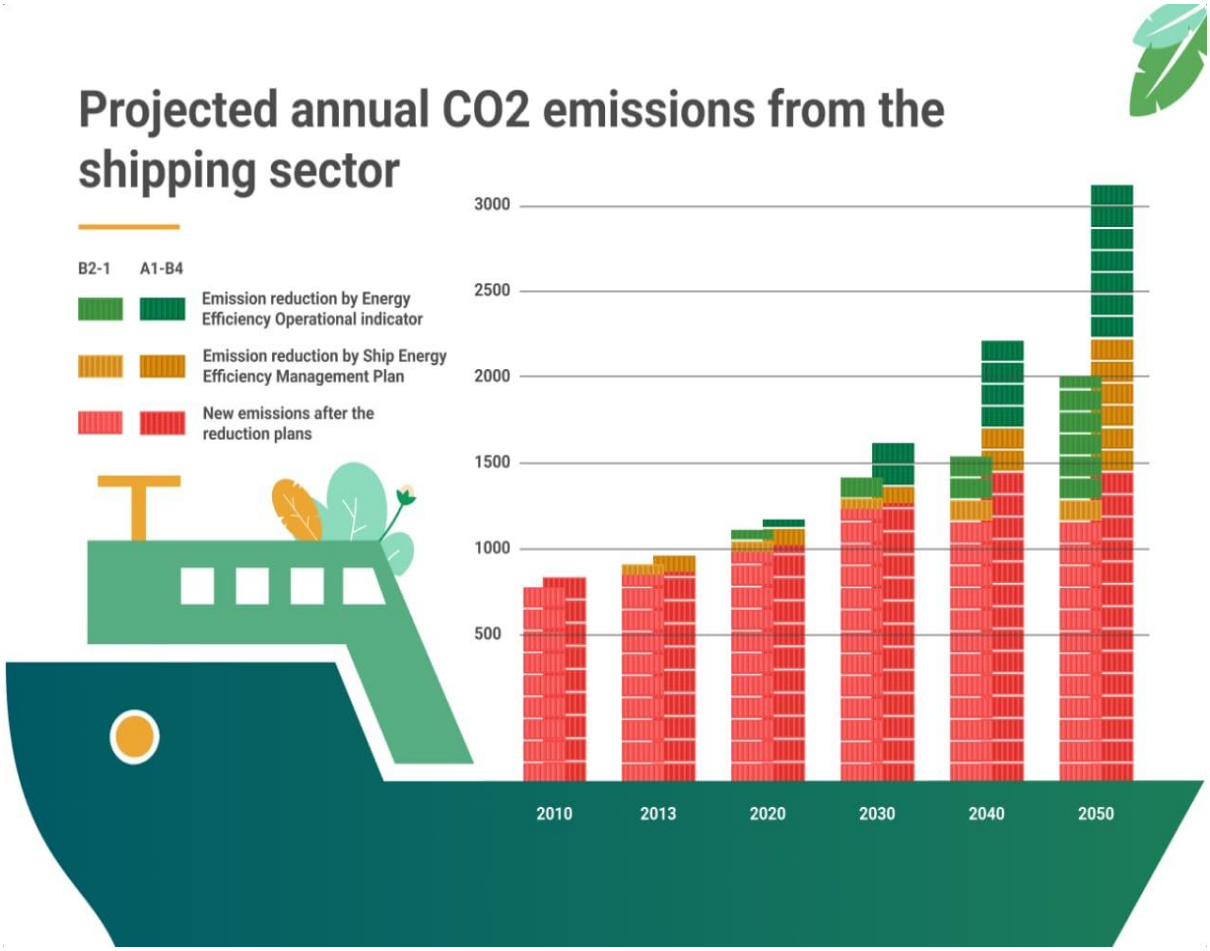
Port Name	**Overall Ranking**
YANGSHAN	1
SALALAH	2
CARTAGENA (COLOMBIA)	3
TANGER-MEDITERRANEAN	4
TANJUNG PELEPAS	5

CHIWAN	6
CAI MEP	7
GUANGZHOU	8
YOKOHAMA	9
ALGECIRAS	10

Table5.3. Port Rankings

Source: https://www.worldbank.org/global-container-port-performance-ranking

As per the **Container Port Performance Index (CPPI),** produced by the World Bank and S&P Global Market Intelligence, ranks 405 of the world's container ports on their performance levels. And the latest index reveals some shifts in the maritime landscape. Regional disruptions impacted port performance across the board, said the World Bank. And with shipping accounting for up to 3% of global greenhouse gas (GHG) emissions, the industry is looking to ensure efficiency improvements are also sustainable ones, with 'green ports' increasingly gaining traction.



Sources: www.mdpi.com%2F2071

Fig5.1 Annual Co2 Emissions from the Shipping Sector

Top CO_2 Emitting Countries (2024)

Rank	Country	CO_2 Emissions (Mt CO_2)	% of World CO_2 Emissions
1	China	12667	32.88%
2	United States of America	5057	12.60%
3	India	2830	6.99%
4	Russia	2032	4.96%
5	Japan	1083	2.81%
6	Indonesia	729	1.80%
7	Germany	673	1.75%
8	Iran	691	1.78%
9	Saudi Arabia	663	1.66%
10	South Korea	636	1.53%

Table5.4. Top CO_2 Emitting Countries (2024)

Sources: edgar.jrc.ec.europa.eu/report_2024

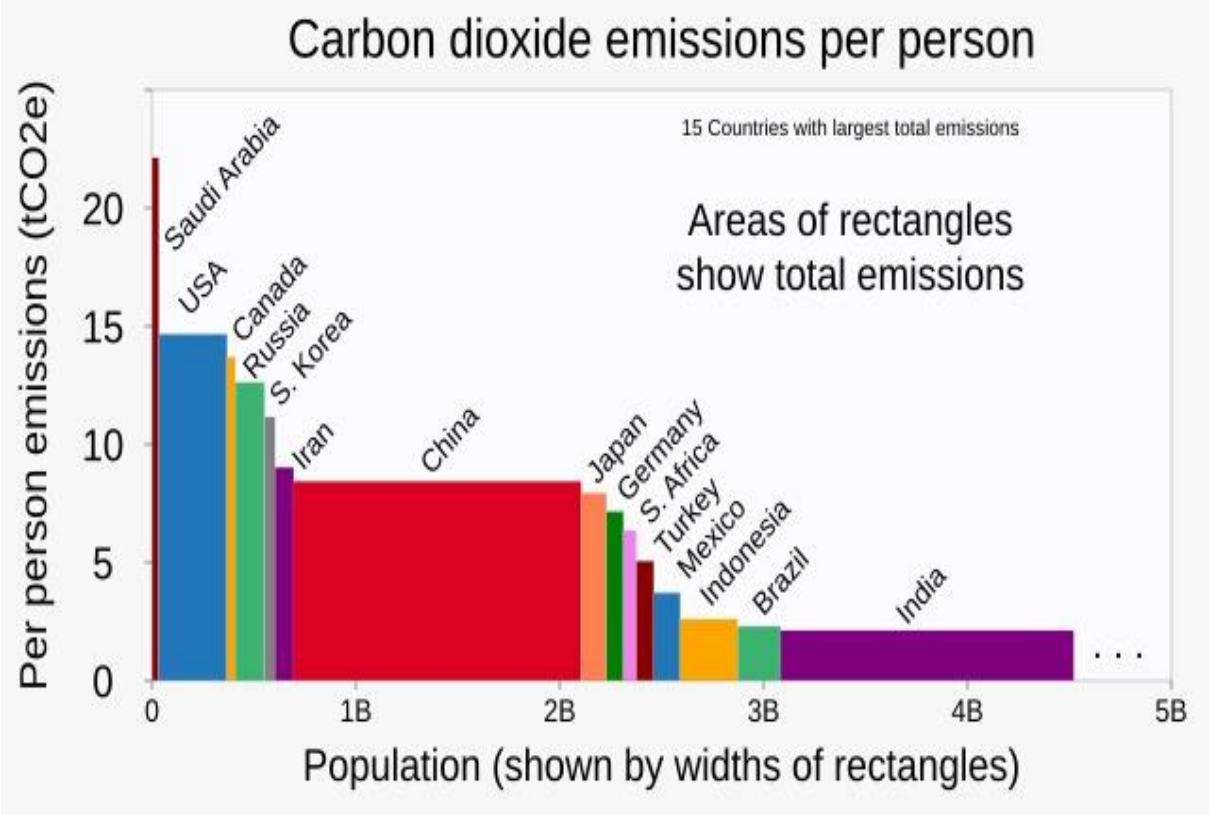


Fig5.2. Carbon dioxide emissions per person

Sources: [montaigbakhtinian.com- carbon-dioxide-emissions-per-person-]

Top 10 Countries CO2 Emissions Per Capita 2024

Palau: With 59.00tonnes of CO_2 per person, Palau tops the list. This high number is mainly due to the country's reliance on diesel-fired power stations and transportation between its many islands.

Qatar: At 35.52tonnes per person, Qatar's emissions are driven by its significant oil and gas industry.

Kuwait: Emitting 24.90tonnes per person, Kuwait's carbon footprint is also fueled by its oil-rich economy.

United Arab Emirates: With 21.75tonnes per person, the UAE's carbon footprint reflects its status as a global business hub and oil exporter.

Bahrain: Bahrain's emissions are 21.31tonnes per person, closely linked to its industrial sector.

Rank	Country	CO_2 Emissions per Capita (tonnes)
1	Palau	59.00
2	Qatar	35.52
3	Kuwait	24.90
4	United Arab Emirates	21.75
5	Bahrain	21.31
6	Trinidad and Tobago	21.17
7	Brunei	20.65
8	Gibraltar	18.96
9	New Caledonia	18.24
10	Oman	17.09

Table5.5 Top 10 Countries CO2 Emissions Per Capita 2024

Sources: https://ourworldindata.org/grapher/co-emissions-per-capita

Top Environmental Priorities of Mega Ports and EU Ports (2024)

Priority	Mega ports	EU port sector (ESPO, 2024)
1	Climate change	Climate change
2	Air quality	Air quality
3	Water quality	Energy efficiency
4	Port development (water related)	Noise
5	Port development (land related)	Water quality
6	Relationship with local community	Ship waste
7	Noise	Relationship with local community
8	Garbage/Port waste	Port development (land related)
9	Ship waste	Garbage/Port waste
10	Dust	Port Development (water)

Table5.6. Top Environmental Priorities of Mega Ports and EU Ports (2024)

Sources: https://www.ecoports.com/publications/top-10-environmental-priorities-2024

Fig5.3. Environmental Priorities of Mega Ports

sources: www.docksthefuture.eu%2Fdocks-the-future-dtf-defining-the-concept-of-the-sustainable-future-

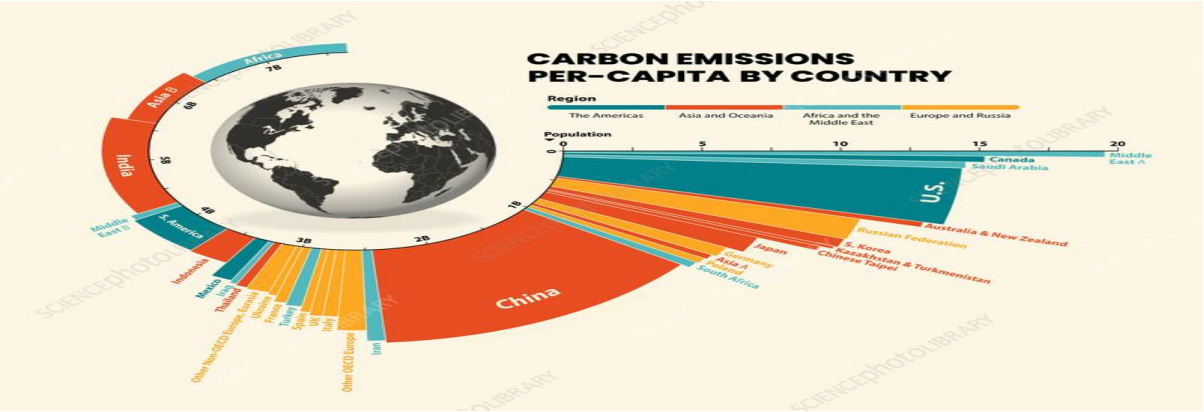


Fig5.4. Carbon Emissions per-capita by country

Sources: www.sciencephoto.com co2-emissions-per-capita-

EMISSION SOURCE TABLE

Emission Source Category	Emission Source	Description
Marine Vessels	Poole based or owned or controlled vessels	Emissions from fuel consumption in vessels owned or controlled by organizations within the cluster or are based within Poole. Emissions within this source group were sub-divided into the following categories: -Emissions whilst at berth - Emissions whilst in transit to the harbor limits • Total fuel consumption outside of the harbor limits for locally focused vessels, such as harbor launches, marine operations and tugs
	Third party vessels	Emissions from fuel consumption in third party vessels. -Emissions whilst at berth - Emissions whilst in transit to the harbor limits

Buildings	Fuel consumption	Fuel consumption within buildings, such as diesel, gas and kerosene within generators, on-site boilers and other static plant and equipment.
	Electricity consumption	Electricity consumption across the port estate.
Landside	Port operations	Mobile plant and equipment operating across the port estate, including forklifts, ship to shore cranes and reach stackers. In addition, other port related activities such as waste disposal were included within this source.
	Road traffic (owned or controlled vehicles)	Road vehicles owned or controlled by organizations within the cluster. The boundary for this source group included all fuel consumption within these vehicles, even if the vehicles travelled outside of the port estate.
	Road traffic (third party vehicles)	Road vehicles owned by third parties, such as ferry passengers, third party haliuers and employee commuting.

5.2. Implications of green port strategies for sustainable port operations

- **Reduced Carbon Footprint**

Reduced Greenhouse Gas Emissions: Switching to cleaner fuel sources such as renewable energy (solar, wind), electrifying port machinery (cranes, vehicles), and offering shore power to docked ships drastically reduced fossil fuel burning emissions.

Cleaner Air Quality: Lower emissions of particulate matter, nitrogen oxides, and sulfur oxides mean cleaner air within and around port locations, improving the health of workers within the ports and surrounding communities.

Energy Efficiency: Adoption of smart energy management systems, LED lighting, and improving operational processes reduce overall energy use.

- **Mitigation of Environmental Issues**

Water Quality Protection: Improved ballast water management, avoided oil spills, and sophisticated wastewater treatment systems avoid pollution of marine environments.

Waste Reduction and Management: Adoption of recycling initiatives, composting of organic waste, and treating dangerous materials securely reduce landfill waste and pollution.

Noise and Light Pollution Control: Using quieter electric equipment, noise reduction methods, and maximizing lighting minimize wildlife and surrounding community disturbance.

Habitat Conservation and Biodiversity: Sustainable dredging methods, green spaces within port developments, and inhibiting the growth of invasive species conserve marine and terrestrial biodiversity.

Climate Change Adaptation: Investing in resilient infrastructure and formulating measures to withstand the impact of extreme weather conditions such as flooding secures port operations and the adjacent areas.

- **Improved Sustainability and Resilience**

- **Resource Efficiency**: Green approaches facilitate efficient usage of water, energy, and materials, resulting in cost benefits and lower environmental footprint.

Circular Economy Principles: Promoting reuse and recycling of materials throughout port operations makes the economy more circular in nature.

Long-term Viability: Environmental considerations can help ports secure their long-term viability in operations and sustain a beneficial relationship with stakeholders and communities.

Green Investments Attraction: By upholding the principle of sustainability, ports can attract environmentally friendly businesses and funding organizations as investments.

Examples of Green Port Strategies

- **Adoption of Renewable Energy:**

Port of Rotterdam (Netherlands): Placed solar panels on port structures and considering wind power.

Port of Hamburg (Germany): Integrated solar and wind power into operations.

Fiji Ports: Deployed solar PV systems to decrease dependence on diesel.

- **Electrification of Equipment and Vessels:**

Port of Los Angeles (USA): Implemented electric cranes and zero-emission cargo handling equipment.

Port of Rotterdam (Netherlands): Investing significantly in the electrification of its network.

Port of Singapore: Employing automated guided vehicles (AGVs) using electricity.

- **Shore Power (Cold Ironing):**

USA, German, and Swedish ports: Supply shore power to the ships to plug in to the grid when in harbor, decreasing emissions from auxiliary engines.

Port of Kapellskar (Sweden): Supplies shore power hookups to decrease air pollution.

- **Alternative Fuels:**

Different ports: Investigating the potential use of Liquefied Natural Gas (LNG), hydrogen, and biofuels for ships and port machines.

Port of Rotterdam (Netherlands) and Port of Tyne (UK): Fitting hydrogen-powered terminal vehicles and biomass-powered equipment.

- **Waste Management and Circularity**:

Port of Los Angeles (USA): Overall recycling systems for different materials.

Most ports: Establishing waste segregation systems and collaborating with recycling plants.

Water Management:

Most ports: Establishing rainwater harvesting systems and water quality monitoring to avoid pollution.

Sustainable dredging ports: Recycling dredged material to reduce damage to marine ecosystems.

- **Smart Technologies and Automation:**

Port of Singapore: Leveraging AI and automation to maximize energy efficiency and minimize emissions.

Multiple ports: Utilizing AI-based energy management solutions to anticipate and maximize power usage.

By implementing these green port initiatives into action, ports globally are making their carbon footprint, reducing their ecological footprint, and securing a greener future for shipping. The particular measures taken tend to vary depending on the size, location, and particular environmental concerns of the port.

CHAPTER - VI

CONCLUSION AND RECOMMENDATIONS

6.1. Summary of key findings

A comprehensive analysis of green port strategies for environmentally sustainable port operations indicates a rising worldwide resolve to decrease environmental footprints with continued operational efficiency.

- **Emphasis on Decarbonization**: Sustained focus on analytical and operational steps towards decarbonization, with a special emphasis at the ship port.
- **Technological process**: Increased use of smart port, IOT, Artificial Intelligence, Blockchain and data analytics to maximize performance and environmental efficiency.
- **Small ports:** Specialized studies and specific solutions are required for small ports, which tend to possess lower economies of scale, restricted funds and aged infrastructure.
- **Consideration of climate change Adaptation:** Integration of climate change adaptation and minor actions in port policies and goals.

Significant findings highlight the universal implementation of Environmental Management Systems (EMS), including ISO 14001, which offer systematic means of monitoring and enhancing environmental performance.

- Ports are increasingly introducing emission reduction measures such as the application of shore power (cold ironing), use of cleaner fuels such as LNG, and electrification of port equipment and vehicles.

- Energy efficiency becomes the focal strategy, with renewable energy systems (solar and wind) and smart energy systems improving sustainability. Waste management also becomes better, with waste reduction, recycling, and minimization of marine litter being the priority.

- Water and noise pollution control measures are also seen, with state-of-the-art treatment facilities and soundproofing systems being utilized. Incorporation of sustainable logistics solutions, including enhanced rail and inland waterway connectivity, leads to decreased road traffic and carbon emissions.

Successful implementation of green strategies requires effective stakeholder involvement, from port authorities through shipping companies to regulators and host communities.

- Schemes of incentives such as exemption of port charges for environmentally friendly ships and marks of certification, such as the Eco Ports standard, are instilling sustainable maritime practices.

- Means of monitoring and reporting, through performance indicators as well as publication of sustainability reports, ensure openness and ongoing development.
- Despite these developments, troubles still loom, most notably high implementation expenditure, technological limitations, regulatory obstacles, and opposition to transformation.

- This research concludes that strategic planning, technological development, policy support, and cooperation among stakeholders can influence the push toward sustainability for port operations immensely.

- These results highlight the prominence of green port strategies as vital pillars of the world's shift towards environmentally sustainable maritime logistics and port management.

6.2. Recommendations for port authorities, policymakers, and stakeholders

- **For Port Authorities**:

Create and Put in Integration of Green Port Roadmaps: Create quantifiable, stepwise goals for waste management, water conservation, energy efficiency, and emissions reduction. For instance, the "Energy Transition" program of the Port of Rotterdam has specific objectives for lowering carbon emissions and switching to renewable energy by 2050.

Invest in Green Infrastructure and Technology: Invest in energy-efficient lighting, renewable energy generation (wind, solar), electric or hybrid cargo handling equipment, and

shore power for berthed boats. To enable ships to connect to the grid rather of using their auxiliary engines, the Port of Los Angeles has also made large investments in shore power infrastructure.

Promote Circular Economy Practices: Implement systems for trash segregation, recycling, and reuse in port operations. Investigate joint ventures with sectors that could benefit from port-generated waste streams. Reusing dredged material is one of the many circular economy activities being promoted by the Port of Amsterdam.

Improve Data Collection and Monitoring: Create effective mechanisms for tracking environmental performance metrics, such as waste management, energy stimulation, and air and water quality. Data is essential for measuring progress and making well-informed decisions.

Encourage Cooperation and Knowledge Sharing: Partner with other ports, research institutions, and technology providers to exchange best practices and lessons learned in green port operations. Participate in international forums and networks focused on sustainable port growth.

- **For Policymakers**:

Establish Strong Regulatory Requirements and Incentives: Implement consistent and strong environmental regulations for port operations, including emissions controls, waste management practices, and water quality controls. Offer economic incentives (e.g., tax breaks, grants) to ports and shipping lines to implement green technology and strategies. The **European Union's "Fit for 55"** package includes measures to encourage sustainable maritime transport.

Support Research and Development: Fund research studies focused on developing and deploying green technologies and solutions to the port and shipping sector. Examples are alternative fuel research, autonomous shipping, and advanced emission reduction systems.

Integrate Green Port Factors into National Transport Planning: Integrate green port considerations in national transportation plans. Enact green port targets as part of national

transportation and environmental policy. Recognize the significant contribution of ports to national climate change goals.

- **For Stakeholders (Shipping Lines, Terminal Operators, Local Communities, NGOs)**:

Participate Actively in Consultation and Cooperation: Participate actively in green port project consultations and working groups. Share your insights and views based on your own specific expertise and interests.

Encourage Sustainable Habits: Shipping lines need to invest in energy-efficient vessels and explore alternative fuels. Terminal operators need to upgrade energy-efficient equipment and environmentally friendly cargo handling techniques.

Green Port Initiative Support: Encourage and facilitate the implementation of green port policies. Recognize the long-term benefits of greener port operations to the environment, economy, and local population.

Foster Transparency and Accountability: They need to be made transparent about their environmental record and institute mechanisms of accountability. NGOs play a key role in monitoring progress and pushing for more environmental protection.

6.3. Conclusion

In Conclusion this research highlights the central importance of green port strategies to sustainable port performance. My research finds the green port strategies concept involves a wide-ranging set of activities whose purpose is to reduce the environmental impact of port operations, improving economic performance and social welfare. These approaches vary from the use of good energy and deployment of energy-efficient equipment to the reduction of logistics and stakeholder involvement. The comparison of various port deployments worldwide showcases the real paybacks of these strategies.

We saw notable decreases in GHG emissions, better air and water quality, and richer biodiversity in and about the port zones. In addition, the implementation of greener energy and practices frequently means cost-effectiveness in the lowered energy usage and waste management costs, thus enhancing economic sustainability in port operations. At the social

level, green port activities lead to better relations with communities, improved OH&S and green job creation. Instead of this, the research also outlines some important challenges that are inherent in the mass implementation of green port policies. These include the initial capital costs, requirements for strong regulatory mechanisms and incentives, technological constraints, and complexities of coordination across different stakeholders. To get beyond these obstacles, port authorities, shipping companies, governments, IT companies, and local communities must work together. Ports may lessen their negative effects, increase their operational efficiency, and create a sustainable supply chain by proactively implementing eco-friendly practices. Future research must focus on developing standardized metrics to assess the effectiveness of different green port strategies, investigating new financing options, and analyzing the long-term socioeconomic impacts of these initiatives. Additionally, case studies of successful green port implementations in diverse geographic contexts would provide valuable insights for broader implementation.

6.4. Bibliography

Bergqvist R, Monios J*Elsevier, (2019), 1-17 Green Ports in Theory and Practice*

Gasparotti C, Mincu G, Țurcanu A (2023) Ports Digitization-A Challenge for Sustainable Development Romanian Journal of Economic Forecasting-XXVI (2)

Psaraftis H, Zis T *Maritime Transport Research (2021) Shipping decarbonization and green ports*

Lam J, Li K *Transport Policy (2019) 84 73-81 Green port marketing for sustainable growth and development*

Tseng P, Ng M *Maritime Business Review (2020) 6(2) 188-203 Assessment of port environmental protection in Taiwan*

Alzate P, Isaza G, […] Hernandez D (2023) *Marine Systems and Ocean Technology Operational efficiency and sustainability in smart ports: a comprehensive review*

Islam M, Aziz M, Khan M *Journal of Agroforestry and Environment (2022) 15(1) 36-42 Strategies to Reduce Carbon Footprint in Port and Terminal Operations: Evidence from a Developing Country*

Azhar Z, Mardiana H, Hidayat D, Rahmawati A (2022) The Implementation of Smart Port in Tanjung Priok Port for Utilization and Green Port Optimization

Kersasyudha Prasetya J, Pahlevi F, Fiva Akira Sembiring H (2023) GREEN PORT OPTIMIZATION TO BUILD AN ENVIRONMENTALLY FRIENDLY AREA IN TANJUNG PRIOK PORT

Zhou K, Yuan X, […] Li R *Sustainability (Switzerland) (2024) 16(10) Research on Sustainable Port: Evaluation of Green Port Policies on China's Coasts*

Sibaouaih S, Roky A, […] Mohiuddin K *Monthly Journal by TWASP (2021) 4(2) 85-99 A Systematic Literature Review of Green Ports Strategies in Sustainable Port Planning*

Ningrat A, Adisasmita S, […] Hustim M *International Journal of Engineering Trends and Technology (2024) 72(2) 154-162 Green Port Performance Criteria Model in A Sustainable Maritime Transportation System in Makassar Port*

Satta G, Vitellaro F, […] Risitano M *Maritime Economics and Logistics (2024) Green strategies in ports: a stakeholder management perspective*

Elhamed H, Mohamed S *African J. Biol. Sci (2023) 19(1) 79-100 Implementing green port policies for the sustainability of the Egyptian ports: Case Study (Damietta Port)*

Huang X, Wang Y, […] Chen J *Transport (2020) 35(5) 454-461 Evaluation of port efficiency in Shanghai port and Busan port based on three-stage dea model with environmental concerns*

Żukowska S *Prace Komisji Geografii Komunikacji PTG (2020) 23(3) 61-68 Concept of Green Ports. Case study of the Seaport in Gdynia*

UÇDU G, KILIÇ A*Deniz Taşımacılığı ve Lojistiği Dergisi (2022) 3(1) 35-49 Investigation of Turkish Ports Within the Scope of Port Location Selection and Green Port.*

6.4. References

maritimeducation.com/sustainable-and-green-ports

www.worldshipping.org/

www.docksthefuture.eu -the-sustainable-future-

www.mdpi.com/

shipmin.gov.in/sites

porteconomicsmanagement.org /green-port-governance/

opentransportationjournal.com

www.tandfonline.com5

oxfordclimatesociety.com/green-ports-sustainable-maritime-trade

https://www.porttechnology.org/

www.c40.org/