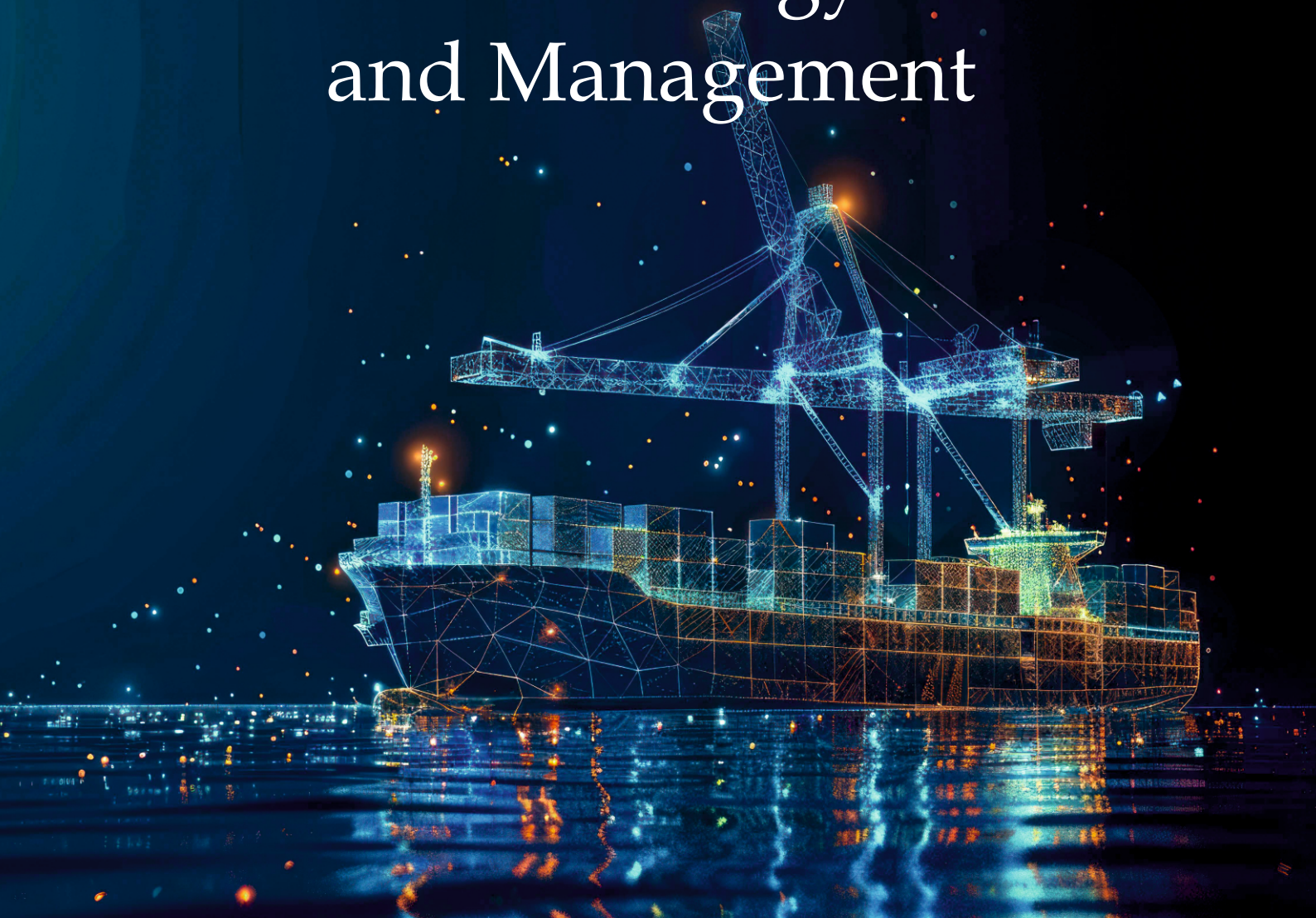


Maritime Digitalization, Finance, Technology and Management



Dr. Tanuja Kaushik
Dr. Dharmesh Raval
Dr. Chandrakant Upadhyay
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Dr. Mayuri Neve



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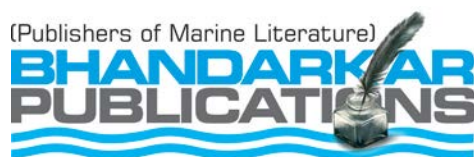
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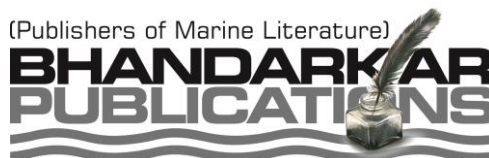
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MESSAGE

This is indeed heartening to know that faculty members and scholars of Gujarat Maritime University are publishing their research work in the form of a book. One of the key roles of Educational institutions is to conduct research and help it penetrate deep in improving the knowledge base and address challenges faced by industry. Research when conducted in the right direction contributes immensely in opening new avenues of learning, skilling, employment and economic growth.

Research should also help in improving the overall communication abilities of the scholars who are expected to contribute to their future recruiters through their written and oral communication skills. A research well conducted will help scholars in not only obtaining a very rewarding job but also a respect and admiration for their interest in academics and scholarly pursuits.

Today the youth of India are having huge prospects in the form of employment opportunities in fast growing businesses both in the country and abroad. A scholar who gains deep insights about the maritime sector and related fields is poised to take a leadership role with his knowledge about the sector and his vision of the future. A well thought research can certainly provide a boost to the confidence of the scholars and prepare them for the challenges they would encounter in coming times.

I wish all the success to faculty members and scholars of Gujarat Maritime University for addressing the gap of industry problems by effective research.

[M.K. Das]

Chief Secretary, Govt. of Gujarat
President, Gujarat Maritime University

MESSAGE

It gives me immense pleasure to acknowledge the publication of the edited volume titled “*Maritime Digitalization, Finance, Technology and Management*”, a significant academic milestone that reflects the collective intellectual effort of our scholars and faculty mentors. This compilation stands as a testament to Gujarat Maritime University’s commitment to fostering research, innovation, and interdisciplinary learning in the evolving maritime domain.

The book brings together scholarly contributions under five well-defined sub-themes, namely digital transformation in maritime logistics and supply chains, shipping management and operations, maritime workforce and infrastructure development, shipping finance and risk management, and smart ports with sustainable maritime systems. Each section encapsulates contemporary issues and emerging perspectives that are critical to understanding and shaping the future of the global maritime industry.

What makes this initiative truly commendable is the active participation of scholars, guided by dedicated faculty mentors, in producing research-driven articles and papers. This collaborative academic exercise not only enhances research aptitude but also cultivates analytical thinking, industry relevance, and scholarly writing skills among our scholars.

I extend my sincere appreciation to the editorial team for their vision and meticulous effort in curating this volume, and to Bhandarkar Publications for supporting its publication. I also commend the contributing authors for their dedication and academic rigor.

It is my firm belief that this publication will serve as a valuable reference for academicians, practitioners, and policymakers alike, and will contribute meaningfully to the discourse on maritime digitalization, finance, technology, and management. I congratulate all contributors on this landmark achievement and wish Gujarat Maritime University continued success in its academic and research endeavors.

Prof. (Dr.) S. Shanthakumar
Provost, Gujarat Maritime University

PREFACE

Rapid digital innovation, changing global trade patterns, and a growing focus on sustainability and resilience have set the marine industry at a pivotal crossroads. The timely academic edited volume titled "**Maritime Digitalization, Finance, Technology and Management**" depicts these shifts through the eyes of up-and-coming scholars mentored and guided by Gujarat Maritime University faculty. An active intellectual ecology that fosters inquiry, critical thinking, and practical research is reflected in this edited volume. Faculty members who have edited this volume have carefully supervised, vetted, and curated a wide range of scholar-led research submissions. The chapters embody Gujarat Maritime University's collaborative atmosphere, mentorship-driven learning, and academic rigor.

Each of the book's five sections delves deeply into important topics of maritime study utilizing suitable research approaches.

The first section is called "**Digital Transformation in Maritime Logistics and Supply Chain**". It has four articles. The first article by Ganga S. talks about Twin technology. This study looks at the problems that stop people from using this technology and the things that people do not know about it. It shows how we can get rid of these problems.

The second article by Missbah Shaikh is about how people in the maritime industry think about blockchain. The maritime industry is changing because of blockchain technology. It is making things more transparent and secure. Before there were a lot of problems because of paperwork. This study says that we need to teach people about blockchain and start some projects to show how it works. The study uses examples from India to make its point.

The third article by Vraj Parikh is about how digital transformation is changing maritime logistics. It looks at how blockchain is being used in the Gujarat region. This study shows how blockchain technology can help by giving everyone the information. It can stop people from doing things which can lead to mistakes and fights. The study says that blockchain can help the maritime sector in Gujarat become more modern and competitive. It can make information flow better. Make things more efficient.

The fourth article by Dhruvin Jadav is about how blockchain can help with logistics. This is when food gets spoiled or rejected. The study says that using blockchain technology can make this process better. It can help people make decisions and follow the rules. It can also help the environment by making the supply chain more sustainable. Digital transformation in logistics and supply chain is very important. Blockchain technology is a part of this.

The second section, "**Management of Shipping Companies and Operations**" has five articles. The first article by Russica Chauhan studies the Trends of the Chartering Market before and after COVID-19. The chartering market was stable before COVID-19. It was influenced by trade, oil prices and supply and demand. The article checks how chartering practices in shipping changed after the pandemic.

The second article by Glory Pandit talks about the potential of Mumbai port as a cruise hub. The study checks if Mumbai cruise terminal can be a cruise hub. It looks at infrastructure, governance and port-city integration. The study finds that Mumbai port has infrastructure and policies. It has problems with coordination, connectivity and sustainability.

The third article by Tirth Bhatt looks at trends in freight forwarding in India. The study checks how digital technologies are changing freight forwarding. It finds that digital technologies improve coordination and efficiency in freight forwarding.

The fourth article by Dharmik Fofandi is about ship recycling in India. The study checks what factors influence ship disposal decisions. It finds that economic factors, regulations and sustainability are important.

The fifth article by Parva Nariya compares container imbalance in ports. The study checks container imbalance at ports, like Mundra Port and Cochin Port. It aims to improve efficiency in India's logistics sector and encourage sustainable container management.

The third section titled, "**Maritime Workforce and Infrastructure Development**", has three articles. The first article by Aatman Pathak, is about the transformation of Shore Level Maritime Professionals to Logistics Personnel in the Modern Shipping Era. This study attempts to evaluate the current state of shore-based professionals in the maritime industry and to propose a tripartite competency framework, comprising core, functional, and leadership competencies, specifically tailored for the freight forwarding sector. The findings underscore the need for maritime organisations to transition from tenure-based to competency-based approaches in recruitment and performance evaluation. The study strongly advocates for industry-wide standardisation of these competencies to build a future-ready workforce in the freight forwarding domain.

The second article by Priya Kumari studies the Factors Leading Asian Seafarers Satisfaction in the era of Digital Transformation. Study highlights human-centred elements substantially outweigh the impact of material factors alone. Training, open communication, cultural adaptation, and English language proficiency are particularly vital in multicultural crew environments, as they foster confidence, reduce interpersonal conflict, and enhance overall wellbeing. It is observed that key stressors such as isolation, heavy workloads, and crew tensions negatively affect satisfaction; however, their influence is notably diminished in the presence of robust social and organisational support. Effective leadership, team cohesion, cultural integration, and clear communication consistently emerge as the strongest drivers of seafarer job satisfaction.

The third article by Chirag Nawani is about the role of Leadership in Maritime Infrastructure. The study explores the critical role of the human element in maritime infrastructure development, with a particular focus on leadership. The research highlights that the most pressing challenges in the sector are not technological or financial, but human-centred: fear of new technology and lack of trust within supply chains. The study underscores the need to develop visionary leaders alongside physical infrastructure to ensure sustainable maritime progress.

The fourth section titled, "**Shipping Finance, Insurance and Risk Management**", has three articles. The first article by Dhaivat Thakkar is focusing on Risk Management and Role of Marine Insurance in International Shipping. The study examines key aspects of marine cargo insurance through four primary objectives. The first investigates marine accidents leading to cargo loss, focusing on the ten major trade routes. The second objective explores common reasons for cargo claim rejections, supported by practical case studies. The third examines real-world challenges in marine cargo insurance. The fourth objective reviews recent developments in marine cargo insurance in India and abroad, with a focus on Europe, which recorded the highest insurance revenue in 2023.

The second article by Bhatt Tirth is about Financing of Port Infrastructure Development in Gujarat. With particular reference to financial performance and Public-Private Partnerships (PPP), this study intends to investigate and analyse the financing of port infrastructure development in Gujarat. This article also highlights that PPP plays an important role in financing port infrastructure development and alleviates the financial burden of the government.

The third article by Om Kothari, is highlighting Impact of Global Disruptions on freight rates in container shipping. This study examines the impact of global disruptions, particularly

the COVID-19 pandemic, on freight rates in the container shipping industry, which handles 80–90% of global trade. The analysis focused on three core objectives: the effect of COVID-19 on freight rates, the role of surcharges in escalating costs, and the consequences of rate volatility for freight forwarders. The study highlights unequal cost burdens, with shipping lines achieving record profits while forwarders and consumers bore substantial losses.

The fifth section titled, “**Smart Ports and Sustainable Maritime Systems**”, has three articles. The first article by Riya Patel is about Sustainable Operational Practices in Ports. The study is carried out through an exploratory and descriptive research design, relying on extensive secondary data from academic journals, industry reports, and global case studies. The study identifies key dimensions of sustainable port development, including renewable energy adoption, digitalization, automation, energy efficiency, and environmental management. The study offers insights and highlights the importance of aligning port operations with international frameworks and national maritime policies, while also emphasizing managerial strategies for achieving efficient and sustainable port operations.

The second article by Ranveer is about Automation of Container Terminals and Impact on Global Trade. This study aims to examine the impact of container terminal automation on global trade, particularly in terms of efficiency, competitiveness, and supply chain resilience. The study conducts a comparative assessment of automated and traditional terminals across key performance indicators, including ship turnaround time, container handling efficiency, berth productivity, and resilience to disruptions such as COVID-19. The findings indicate that automation significantly enhances operational efficiency and reliability, though challenges such as high capital investment, labor displacement, and longer payback periods persist.

The third article by Raj Choudhary is about Global Trade through Smart Port and Integrated Port Management. This study examines the role of automation, digitization, and digitalization in enhancing port performance and global supply chain efficiency, with a particular focus on Indian ports. It highlights the impact of technologies such as automated cranes, IoT-enabled systems, smart warehousing, and data-driven management on key operational indicators, including vessel turnaround time, cargo throughput, and multimodal connectivity. The findings reveal significant gains in efficiency and coordination, though challenges such as high costs, technological integration, and workforce readiness remain barriers to widespread adoption.

This volume stands out due to its emphasis on practical learning and solid foundation in real-world relevance. Through sustained engagement between scholars and faculty mentors, the research presented in this volume has been thoughtfully shaped, ensuring both strong academic rigor and meaningful real-world relevance. The quality, direction, and coherence of this compilation have been greatly influenced by the faculty's position as mentors and editors.

We sincerely thank all the scholars for their commitment and inquisitiveness. We also thank the faculty mentors who have played a crucial role in making this edited book a reality through their editorial stewardship, advice, and critical insights. We really appreciate the assistant editors' assistance in organizing and assembling this work.

We extend our sincere gratitude to Bhandarkar Publications for their valuable support and collaboration in successfully publishing this volume.

This volume aspires to contribute meaningfully to the evolving body of maritime knowledge by fostering a culture of research, collaboration, and innovation. It stands as a reflection of collective academic endeavour and a commitment to shaping future-ready maritime professionals.

The Editorial Team

About Gujarat Maritime University (GMU)

The Indian maritime sector has been consistently exhibiting remarkable growth and is poised to emerge as a key driver of the future global maritime economy. Gujarat Maritime University (GMU) is a visionary initiative of the Hon'ble Prime Minister of India, Shri Narendrabhai Modi, established in 2019 by the Government of Gujarat through the Gujarat Maritime Board to address critical knowledge and capacity gaps in the maritime sector. Since its inception, GMU has been committed to offering meticulously designed academic programmes that integrate the collective expertise of maritime industry professionals, distinguished academicians, and governmental institutions, enabling the University to emerge as one of India's distinctive maritime-focused universities with curricula aligned to leading global maritime institutions.

GMU is governed by an eminent consortium of senior officials of the Government of Gujarat, prominent industry leaders, and renowned scholars, under the leadership of the Chief Secretary to the Government of Gujarat. This robust governance framework ensures that the University remains agile and responsive to the evolving needs of the maritime sector while consistently upholding the highest academic, professional, and ethical standards. Gujarat Maritime University is mandated to develop as a global centre of excellence in maritime education, research, professional training, and capacity building, with a strong focus on strengthening human and institutional capacity in India and internationally, and advancing high-quality education, research and development, and professional training for the maritime sector worldwide.

The University's academic offerings are thoughtfully designed to meet the growing and diverse demands of the maritime industry. In its first phase, GMU offers a range of Master's, Doctoral (PhD), and Executive Development Programmes focusing on the commercial, regulatory, and strategic dimensions of the maritime value chain, including Maritime Law, Maritime Management, International Trade Law, Shipping, Logistics, and allied disciplines. GMU's bespoke approach to education ensures that students and professionals are equipped with the knowledge, analytical skills, and practical insights required to navigate the complexities of a rapidly changing global maritime landscape.

GMU has signed Memoranda of Understanding (MoUs) and entered into active collaborations with several leading national and international maritime organizations, significantly enhancing academic exposure, industry engagement, research opportunities, and knowledge exchange for students, faculty, and other stakeholders. Its programmes are developed in collaboration with esteemed international institutions such as Erasmus UPT, STC International, and Copenhagen Business School, Denmark, among others, ensuring alignment with global best practices and international standards. In the next phase of development, Gujarat Maritime University plans to expand its academic portfolio by introducing technical and liberal arts disciplines within the maritime domain, further enriching its academic ecosystem and addressing the evolving multidisciplinary needs of the global maritime industry.

About Bhandarkar Publications

The legacy of Bhandarkar Publications is a profound chronicle of nationalist vision and intellectual independence, beginning in 1975 under the foundational leadership of the late Professor K. R. Bhandarkar. A preeminent specialist in Nautical Science and a venerable pedagogue at Lal Bahadur Shastri College (LBS), Prof. Bhandarkar was twice deputed to the United Kingdom by the Government of India under the Colombo Plan. He returned with a mastery of global maritime standards but a sharp critique of their delivery, observing that Indian cadets were tethered to prohibitively expensive, imported British pedagogical materials. Driven by a "Swadeshi" heart, he moved to end this reliance by encouraging the finest Indian teachers and experts to author their own books, ensuring the dissemination of knowledge was rooted in local expertise. As India's first prolific maritime author, he established the nation's first dedicated maritime publishing house, transforming technical literature into accessible, indigenous reference of Ocean Navigation. His genius was not limited to the written word; he was a true inventor who held several patents in his name specifically related to radar and navigational technology, ensuring that the growth of the Indian Merchant Navy was powered by homegrown intellectual property.

As the industry transitioned into the digital era, Captain Vivek Bhandarkar, a Master Mariner, expanded this vision by steering the company to become a global pioneer in maritime EdTech. Decades before "apps" became an industry standard, Bhandarkar Publications was already digitizing the mariner's toolkit. This pioneering spirit achieved a historic milestone when their flagship applications—specifically for Rules of the Road (ROR) and Morse Code - surpassed the one lakh (100,000+) download mark globally, becoming essential digital tools for seafarers in every corner of the world. Beyond its digital ecosystem of 21+ apps and high-fidelity 3D instructional videos, the group has diversified into high-impact industry verticals. These include the widely circulated Bhandarkar Shipping News and the technology wing BITS, which provides the essential software architecture required by the Government of India for the surveillance and tracking of vessels within sovereign waters.

The company's influence now reaches the highest echelons of national governance, evidenced by its 2017 White Paper on maritime policy, which was formally lauded and implemented by the Prime Minister's Office (PMO). Bhandarkar Publications is also the first organization to conceptualize and institute the prestigious Samudra Manthan Awards, honoring the finest performers across the maritime and logistics spectrum. The very concept of the awards, along with the design of its iconic trophy, is inspired by the timeless Indian philosophy of the Churning of the Seas "Samudra Manthan" - symbolizing the pursuit of excellence, the emergence of knowledge, and collective progress. From hosting these prestigious ceremonies and specialized Hazmat seminars to inspiring 6,500 students at the "Samudra Kshitij" exhibition, the firm remains the definitive custodian of India's maritime heritage. This commitment is further solidified through the publication of Samudraprasadanam, a coffee table book celebrating 75 years of Independence, and a strategic research partnership with Gujarat Maritime University (GMU).

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Digital Twin Technology in Maritime Sector with Reference to India

**Ganga S, Gujarat Maritime University*

Abstract

The maritime industry is being overtaken by digital technologies to make the industry more efficient, safer, and sustainable. The Digital Twin (DT) technology, that implies the creation of the virtual twin of an actual object and process, has huge opportunities in the sphere of predictive maintenance of ships, port operation, and congestion management. However, there is a low level of knowledge and readiness regarding the adoption of DT in the Indian maritime sector. This paper will analyze the level of digital twin technology awareness in the Indian maritime stakeholder and will examine the digital twin technology in terms of predictive maintenance, port management, safety, and sustainability in the maritime sector. The collection of primary data using structured questionnaire were done, which adopted a descriptive and exploratory research design whereby the port authority, maritime professionals, students, and Navy personnel. The findings reveal a growing interest in Digital Twin, and perceptions regarding the advantages are positive, yet the challenges to the application of Digital Twin are associated with the high cost of its implementation, the lack of digital infrastructure, expertise, and cyberattacks. This study will have a contribution since it will serve to define the current gaps in awareness and present insights to ensure the successful adoption of digital twin technology in the Indian maritime industry.

Keywords: Digital Twin, Maritime Sector, Predictive Maintenance, Port Management, Operational Efficiency, Sustainability, Smart Ports, Cybersecurity

Introduction

The shipping industry is on a rapid and digital transformation journey, which is necessitated by the necessity to be efficient, sustainable and resilient in the supply chains around the world. The Digital Twin (DT) technology has also taken an enormous portion of the centre stage as one of the emerging technologies as a virtual representation of the actual physical object, process, or system that may enable real-time monitoring, predictive analytics, and optimization (Mauro and Kana, 2023). In the aerospace and manufacturing sectors, there is a vision of digital twins, yet it is applied in a broad range of maritime settings, including ship design, predictive maintenance, port, and logistics management (Judijanto, 2025; Kim, Lee, and Park, 2023). A digital twin ecosystem is the connection between sensors, IoT, artificial intelligence, and simulation models, which create a living-like digital clone that develops alongside the physical one. This is of enormous opportunities to the maritime stakeholders of novel monitoring of hull stress of vessels and engine health (Zhang, Xu, and Wang, 2022; Ahmed and Lee, 2023), ports to track the movements of vessels and cargo (Port of Rotterdam reviewity, 2019) and potentially model entire ocean basins on environmental and climate resilience (European Commission, 2021; DITTO Programme, 2023). Although change has massive potential, it is not equally adopted or shed light on in the industry. The most prominent ports in the digital twin implementation have been the major ones, such as Rotterdam and Corpus Christi, though smaller ports and new maritime economies have been held back by lack of digital infrastructure, initial investment to install the digital capabilities, lack of first-class training personnel, and the risk of cyberattacks (Shi, Lam, and Wang, 2021; Port of Corpus Christi reviewity, 2024). In this case, the study that focuses on awareness and application of the digital twins technology in the maritime environment is timely and relevant. The analysis of the stakeholder perceptions,

readiness and adoption barriers forms the basis of the work in providing an insight into the maritime organizations with regards to adopting the digital innovation and striking a balance between the operational efficiencies, sustainability and resilience in an environment of competitive internationality.

Literature Review

Digital Twin (DT) is seen as a digital transformation that is becoming increasingly popular in the maritime industry. Digital Twin is a virtual representation of physical systems with the ability to monitor, simulate, and optimize physical systems in real-time. It has been indicated in literature that DT has common applications in shipbuilding, ship operations, predictive maintenance, and smart ports. It enhances effectiveness, security, and sustainability with the help of real-time information and innovative technologies such as AI and machine learning. Nonetheless, the factors like high costs, problems with the integration of data, and the absence of standardisation continue to restrain its complete implementation. This paper assesses the application of Digital Twins Technology (DTT) in the marine industry and identifies DTT as one way of facilitating sustainable development and life cycle management in the marine industries like shipbuilding, offshore oil and gas, fisheries, and marine energy (Zhivan et.al., 2023). In addition, the paper also discusses the challenges and future of DTT, in order to emulate smarter and more sustainable utilization of marine resources. Digital twins in the marine industry discuss predictive maintenance on the basis of digital twin technology (PdMDT) in order to overcome the weakness of conventional approaches (Lv, et al. 2023). It describes its principles and advantages and the differences between PdMDT and conventional methods, as well as summarizes its use in fields such as manufacturing, power, construction, aerospace, and shipbuilding. The implementation of PdMDT based on the example of industrial robots is proposed as a reference framework and the challenges and opportunities of PdMDT are discussed. (Zhong, et al. 2023). Overview of predictive maintenance based on digital twin technology.

This paper is a review on the application of machine learning (ML) to digital twin-based predictive maintenance (DT-PdM) and specifically focuses on studies that place the efforts of DT within the context of enhancing the use of maintenance and its performance. It synthesizes, classifies, and examines the application of ML in DT-PdM in a number of varying lifecycles. This paper also speculates on the obstacles and possibilities of ML foresight with regards to the relevant fields of future research concerning an ML-based DT-PdM system. This review is aimed to inform and help in the future research and whether ML would be practically useful to improve DT-PdM systems (Chen, et al. 2023). This paper explains the growing importance of Digital Twins as applied to the issue of predictive maintenance, especially regarding the lack of failure information. Digital Twins can be used to support more effective and sustainable maintenance plans, as it predicts machine behavior using real-time and condition-based degradation. The fact that the relevant research is growing exponentially since 2018 means that a systematic review of this emerging area should be conducted. A Digital Twin-inspired collaborative model presented in this paper aims to help in solving the problems of predictive maintenance (PdM) by exchanging multi-organizational information and knowledge (Van Dinter, et al. 2022). It constructs the framework on an integrated mathematical model that introduces uncertainty in the model that is solved using the NSGA-II hybrid algorithm and dynamic plan adjustment process. An example of a case study that explored grinding roll bearings shows how this approach can be applicable in decision-making of PdM that would be more accurate and reliable.

The Predictive Maintenance (PdM) approaches to Industry 4.0 systems (Feng, et al. 2021). The significance of PdM in terms of asset protection and costs-efficiency is provided in contrast to conventional maintenance. The overview of the existing PdM approaches (facilitated by the IOT, Big Data and ML) that are applied to different applications and the

obstacles and opportunities of its implementation. The real-time Digital Twin (DT) of ships anticipating the ocean wave environment and coupled hydrodynamic performance (seakeeping and maneuverings) of the ship (Shukla, et al. 2022). The developed algorithm, which utilizes measured images of wave-radar to reinstate the field of the waves, and the 3D spatial extrapolation of the wave field can be determined within minutes in the future. The DT predicts the responses of the ship by using a combination of the wave prediction and a real-time coupled seakeeping-maneuvering analysis program, which provides a chance to assess the risks in real time and even predict the optimal path through which to maneuver the ship in a safer and more efficient way. The problem of this paper is identified as the rapid malfunctioning of the complex marine equipment and its unplanned failure because of the variances of loads and the severe conditions of the ocean, which influences the mission capability of a ship (Kim., et al. 2022). It provides an intelligent operation and maintenance (O&M) framework of marine devices in the form of Digital Twin (DT) technology that can be used to manage the whole life cycle of the equipment. It also discusses the present stage of the development of DT technology and in which place DT might be applied during the O&M of the marine equipment and the challenges posed by gravity and gives a roadmap of how to speed up the role of DT as a combat multiplier with respect to improving marine equipment performance.

The presented article is devoted to the concept of a ship's digital twin (SDT), which is proposed to be implemented as a software clone to simulate the situation to save some money, to provide an early notification of unforeseen anomalies, and to reflect on the optimization of the systems functioning on the boards of the separate ship and on the functioning of the ship in general (Wu, et al. 2021). The article is an attempt to introduce SDT, the steps and techniques to be followed in formulation, and a four-step cyclical process to implement SDT. It talks about an application review to assist in future research proposals. The concept of a digital twin (DT) will be advocated as a central tenet of the "Shipyard 4.0" model, which represents the product's "virtual reality" and "Cyber-Physical Space" based on a shipyard's observable and statistical data (Assani, et al. 2022). This paper will argue for the role a DT plays in retaining and/or improving the shipbuilding industry's competitiveness. It identifies that the DT plays a role particularly in "advanced outfitting" which delivers verifiable savings, enhanced environmental protection, and heightened workplace safety over the ship product life cycle. This study explores the important role of Digital Twins (DTs) in the maritime sector, which is experiencing rising delivery costs and decarbonization pressures (Kunkera, et al. 2022). The study examines the current state of the industry, highlights possible use cases for Ship DT applications along the entire product lifecycle, and introduces a paradigmatic Maritime Digital Twin Architecture (MDTA) that aims to standardize and organize practical DT functionality. This research presents a detailed reflection on the evolution, theory, and increasing utilization of Digital Twin (DT) technology in the maritime sector, specifically regarding surface vessels (Giering, & Dyck, 2021). It outlines the relevant changes from the electrification of shipping to the complete adoption of a DT-based system, reviews current DT-based research and applications, and presents a development approach that leads to the introduction of a four-layer DT framework. This research further integrates a comprehensive literature and scientometric studies in order to conceptualize the systematic footprint of DT and to help inform future research relating to the design, development and operation of surface vessels. The Japanese research and development project that relates to the Digital Twin for Ship Structures (DTSS), which assimilates data (Wave Spectrum, Kalman Filter and Inverse FEM) for integrating real-time hull monitoring and numerical simulation (Madusanka, 2023).

The DTSS can greatly enhance the accuracy of predicting ship stress responses and cumulative fatigue damage while underway in waves, providing an optimal, data-driven framework to support ship design, navigation, and maintenance. (Toh & Okada, 2024) This article seeks to the void regarding Digital Twin (DT) adoption in the maritime industry by

methodically examining DT applications and best practice models adopted in the advanced automotive and aviation industries. This study uses the PRISMA framework to classify the types of DT models relative to modelling method and life-cycle phases (Harrison et al., 2020), and presents a five-dimensional DT framework designed for analysis. The analysis of the automotive focus (efficiency, safety enhancements for autonomous/electric vehicles) and the aviation focus (predictive maintenance, pilot/crew training, real-time monitoring) produces a roadmap for maritime knowledge transfer that positions DT to deliver substantial benefit in terms of ship efficiency, safety, and predictive maintenance--albeit with challenges of data management and operational complexity (Mao, et al. (2025). The present paper presents a cost-effective Digital Twin (DT) strategy for monitoring and prognosticating vessel-specific fatigue damage that addresses the problem of conservative design assumptions.

This DT utilizes publicly available operational data (the global vessel position), metocean hindcast data, and computational models, rather than expensive structural sensors, to estimate a vessel's exposure to environmental conditions and cumulative fatigue accumulation over time. The approach is demonstrated in a seven-year containership case study, improving upon the design estimates and then leveraging the data to forecast remaining fatigue life and provide critical vessel-specific decision-support for scheduling maintenance, inspection, and service life extension decisions. The research associated with Digital Twin (DT) applications in the maritime industry. Furthermore, it proposes and discusses its five-dimensional DT model (VanDerHorn, et al., 2022). DT research domains (ships, structures, underwater vehicles, and engines) are classified and model characteristics (target system, contribution to knowledge and research, and simulation method) are explained. Evaluation of DT across the product life-cycle (design, manufacturing, operation, and maintenance) suggests that much of the current research is related to smaller modules or single components, with limited research on the full life-cycle. Overall, this analysis shows that DT technology is still developing in the maritime realm (Mao, et al. (2023). This research advances Underwater Sensor Networks (UWSNs) for marine monitoring by developing a Marine Integrated Communication Network (MICN) based on a Wireless Mesh Network. It introduces a Fish Swarm Optimization Algorithm (FSOA) for optimal sensor coverage and a reliable new combination hybrid automatic repeat request (NC-HARQ) protocol to send data reliably and with a high success rate. The proposed system facilitates an intelligent ship's Digital Twin framework that immensely improves the monitoring of marine data.

This paper develops a Ship Digital Twin (DT) concept for navigation autonomy by monitoring and tracking how a fully autonomous ship responds to its environment and controller changes in real time (Lv, et al. 2022). A validated mathematical maneuvering model of a ship with a twisted rudder is used to represent the physical system. The DT architecture is explored using three simulations, including an autopilot mode and two hard maneuvering cases, to track the ship's response to different controller parameters. The research confirms that the DT concept is effective and exhibits its ability to conduct a controller stability determination to see the most optimum controller gains for the model ship. This paper proposes a management framework for smart ports that is based on Digital Twin (DT) technology to deliver a high-fidelity digital representation, risk predictions, and integration across all components of a smart port's supply chain (Kinaci, 2023). The principal contribution is a systematic framework consisting of five layers of DT-based port management (physical layer, data layer, model layer, service layer, and application layer). The paper discusses the multi-aspect potential applications, including cargo handling, container operations, risk prediction, and protection of the environment. In addition, the paper discusses the current challenges to apply an ideal visual-based management system (i.e., DTs) and provides a high-level review of DT management capabilities and their required architecture in order to support effective simulations and better management of smart port operations across all activities.

This paper discusses about why a standardized comprehension and practically viable application of Digital Twin (DT) technology in complex port systems is essential in addressing expansion in transportation and enhancement of the environmental footprint (Wang, et al., 2021). According to the comprehensive cross-domain literature analysis, smart cities and supply chains are the most similar to the DT of a port. It includes three main requirements of a digital port twin, which include situational awareness, in-depth data analytics that support intelligent decision-making, and a multi-stakeholder governance and collaboration interface. Lastly, it gives an array of operational scenarios to demonstrate how the DT can be deployed to achieve energy savings by having a better utilisation of the port resources, facilities, and operations. This study conducts a comprehensive review of the utilization of Digital Twins (DTs) to promote sustainability along economic, social and environmental trajectories, addressing a gap in the literature regarding real-world implementation (Klar, et al. 2023). The study identifies and organizes 68 digital applications to ten areas of application, and proposes five new applications. The major findings suggest that DTs help achieve sustainability through real-time monitoring and decisions, increased safety and security, improved resource efficiency, and support of the ecosystem. The study ends with a consideration of the key challenges of implementation including: costs, data quality and availability, varied stakeholder goals, and model validation processes and implications for seaport administration and policy formulation.

An overview of the success of the Nexus, a watershed moment for knowledge and innovation in seaports that facilitated international collaboration (Homayouni, et al. (2025). The well-known experts and a range of immersive, engaging formats, serving as a pivotal venue for networking and sharing ideas amongst academics, professionals, and Ibero-American researchers. Engaging sites such as the University of Évora and the Port of Sines Cyber Gym enriched the overall positive experience. Ultimately, DGTMP24 fostered international collaboration and research networks in the interest of sustainable transport and innovations in seaports. The article presents an adaptive Digital Twin (DT) framework that aims to improve the sustainability and resilience of seaports, based on the case of Port of Tyne (Batista, et al. (2025). The study discusses the main challenge to port digitalization – the reliance on increasingly costly IoT systems for integration of petroleum data typically leads to inconsistencies in port asset data. The DT offers a complex plan to formulate emergency response and long-term mitigation pathways, while providing port stakeholders with a decisive operational risk management scheme, international network technology, and a healthy understanding of the complete port-city integrated system. The framework of a Digital Twin (DT) application system is proposed in this paper as the solution to the efficiency bottlenecks experienced by large-scale comprehensive ports as their size and complexity are ever-growing (Jin, & Zhu, 2024). The most crucial innovation is cyber-physical fusion to develop holographic and visual management and control patterns of intelligent port operation. In this paper, the key technologies, such as DT modeling, global ubiquitous perception, data mapping, and model fusion are addressed. To illustrate the design of the DT application system, a case study of the terminals of the Qingdao Port would be provided. The core functions of the three-dimensional visual monitoring and optimal dispatching using real-time data are used in the system to achieve the intelligent operation of the port, which proves to be a significant reference point in the future intelligent operation of large and comprehensive ports. The disruption created by Digital Twins (DTs) in major seaports alongside a prominent case study of their use at EUROGATE container terminal in Hamburg to present use cases (Yang, et al. 2022).

The study analyzes DT maturation, benefits, and barriers to the use of DTs as a driving force behind smart ports and Industry 4.0. Overall this paper shows how DTs can provide simulation-based optimization and improved decision making for processes and maintenance of equipment and identifies barriers of high entry cost and lack of standardization in the industry. This article describes the creation of a 2D Digital Twin (DT) prototype for maritime

ports to address the need for DTs in complex logistics systems (Neugebauer, et al. 2023). The purpose of this virtual model is to improve operational efficiency and environmental performance with two key features: visual simulation of key processes such as berthing and mooring, and machine learning (ML) for accurately predicting vessel arrival times. Additionally, the DT will allow for testing different arrangements of a berth plan and comparing different schedules. This DT prototype paves the way for higher end systems that will assist in growing port operations, efficiency, and energy efficiency. This paper is concerned with the digitalization processes in seaport service quality and redefines quality factors as a stage in digitalization (Calhau, 2024). Considering seaport service quality is not standardized, the research observes how digital technologies adopted in leading seaports where investment is being made enables ports to become, or remain, efficient and competitive. The general aim is to define quality factors and identify areas for improvement within seaport services by examining the digital tools that are being used.

The proposed paper presents a conceptual guide for creating Digital Twins (DTs) within a port infrastructure context for the purposes of lifetime performance management through Structural Health Monitoring (SHM) applications (Agatić, 2024). In contrast to typically focused port DTs which zero in on the normally dynamic, logistical properties, this research is fully focused on preventing concerns caused by monitoring the deterioration of a physical design. The guide identifies the integration of technologies including Unmanned Aerial Vehicle (UAV)-mounted sensors, Geographic Information Systems (GIS), automation technologies, and condition assessments of a structure, to facilitate computer aided twinning. The ability to enable and enhance this process was successfully showcased with a pilot DT application centered on the waterfront facilities at the Lavrio port, Greece. which validated the concept as promising in identifying potentially smart maintenance management options. This paper offers a conceptual guide for creating Digital Twins (DTs) of port assets with the specific goal of lifetime performance management using Structural Health Monitoring (SHM) applications (Christina & Vasiliki, 2024). This is in contrast to the majority of port DTs focused on logistics and cargo movements; the work intends to prevent problems with port structures by simply monitoring the deterioration of physical structures. The guide illustrates using a combination of technologies including Unmanned Aerial Vehicle (UAV)-mounted sensors, Geographic Information Systems (GIS), automation, and structural condition assessments in a way that advances computer-aided twinning.

The overall success of the approach was demonstrated through a pilot DT application on the waterfront facilities of the Lavrio port in Greece, which shows promise for identifying smart maintenance strategies. The paper presents the details of how Systems Engineering, along with Model-Based Engineering, can completely change how cruise ships (a complex product category with significant performance requirements for safety, customer satisfaction, and environmental standards) are designed (Jeon, & Theotokatos, 2024). The primary focus is the Digital Twin (DT) model, which is considered the next logical step in the evolution of Model-Based Engineering. The use of the Digital Twin concept in the construction of cruise ships is described as one of the most promising applications of the Digital Twin due to its extensive life-cycle viewpoint and a systematic process that enables stakeholder involvement in the design process. The present a Digital Twin (DT)-based data management framework for Automated Container Terminals (ACTs) in addressing dynamic data management at multi-resource couplings (Arrichiello & Gualeni, 2019). Establishing that the operation of ACTs should be smooth and efficient, through an understanding of the data from multiple physical systems, the reviews consider ACTs' operational modes and data requirements followed by the proposed DT model, which forms a framework is then proposed for data storage, data interaction, data visualization, and data security for the purpose of achieving synchronization for both operational process mapping and integrated data management. A case study in the ACTs of the Guangdong-Hong Kong-Macao Greater Bay Area is provided to illustrate the application's use and efficacy (Cao, et al. 2025). This article presents the

development of a comprehensive Digital Twin (DT) prototype of the entire research vessel, shifting from the current emphasis on twinning single ship equipment (e.g., engines, cranes).

This research aims to contextualize the state of single equipment in the overall operational context of the vessel, necessary for advancing offshore operational excellence and ship autonomy. The proposed DT architecture is suitable for virtual prototyping and evidence of its practicality is demonstrated in a proof of concept in a remote control center for remote observation and crew assistance during routine control and emergency situations of an offshore crane. (Major, et al. 2021). In this paper, a Cognitive Processes in Human Digital Twin (HDT) model in the maritime domain is proposed in order to improve crew reliability and system safety. The proposed model addresses the current lack of emphasis on human cognitive processes in HDTs by integrating the IDAC model and Discrete Dynamic Event Tree to characterize the dynamic and quantitative changes in crew cognitive state and the decision making process, which is verified with a case study utilizing a ship simulator (Li, et al. 2024). This article talks about the way digital twin technology can assist in decarbonizing the shipping industry by duplicating ships and their operations in a virtual format to maximize ship design, fuel efficiency, and voyage planning; increase efficiencies and safety through the application of AI and edge computing; and facilitate sustainable, low-emissions operations in a maritime context (Karakostas & Katsoulakos 2024).

The research investigates the development and technological maturation of the shipping and marine industry and a comprehensive review of the industry as an important contributor to world trade and emerging economies. There is an increasing amount of effort focused on advancements in shipbuilding and fleet management technologies, but the maritime industry has been slow to embrace digital technology developments such as Artificial Intelligence, virtual reality, and autonomous operating systems. The pace of technological development has been limited by consideration of safety, security, and costs of adoption causing organizations involved in decisive maritime operations to limit the use of intelligent technologies in their business (Markopoulos, et al. 2024). The systematic literature review of previous studies related to Digital Twins (DTs) and their linkage with the Internet of Things (IoT) utilizing reinforced machine learning in manufacturing and logistics systems in the context of Industry 4.0. The key objective is to systematize the literature in order to identify emerging patterns and discuss suggested future research studies.

The review uses the Scopus database to analyse publications dated from 2010 until 2021, and it is a broad review on the topic. Lastly, the paper proposes a framework to create a data-driven DT and reinforced learning paradigm for the development of lean, reactive, and smart production and supply chains. (Abideen, et al. 2021). In this paper, there is an academic discussion about utilizing a digital twin (DT) approach and modeling techniques to mitigate supply chain risks that are often caused by the low reliability and instability in organizational operations. The reviews divide operational faults into two classes; operational risks (uncertainty of supply/demand and disruption to an information flow) and critical risks (force majeure like natural disasters, strikes or fires). The reviews emphasize that DT technologies such as dynamic simulation and analytical optimization models can assist companies in increasing the reliability of supply chains by modeling different scenarios of failure, such as physical or location, temporal, or recovery policies. The reviews assert that there is currently no single unifying model in the literature that proposes a supply chain DT, and they review existing concepts and offer the reviews thoughts on a possible supply chain digital twin. (Barykin, et al. 2020). The development of a control-oriented Digital Twin (DT) for the Wärtsilä 4L20 marine engine, to meet strict emission targets, is presented in this paper.

The detailed model was reduced to a Fast-Running Model (FRM) that achieves simulation results three times faster than real-time with a less than 5% error in accuracy. The advantageous balance between speed and fidelity demonstrated the viability of using an FRM based on physics principles in the marine industry for advanced control, hardware-in-

the-loop simulation, and incorporation of predictive emission sub-models. The review covers the definition and development of Digital Twin (DT) with respect to its role in digitalization of large maritime structures, such as ships and offshore platforms (Hautala, et al. 2022) . The primary intent here is to support the case for a need to have a more realistic representation of virtual structural models that can help connect design and construction with reality. This review considers current applications and issues and supporting technologies for structural DT through all lifecycle phases (design, construction, and in-service life) and ends with recommendations for possible areas of future research. (Chen, et al. 2021).

A new Gradient Boosting Machine (GBM) methodology is proposed for the development of a Digital Twin (DT) model used to predict voyage performance in ocean vessels, which is an important step in mitigating GHG emissions. The model is developed by augmenting standard Noon Reports (NR) and Automatic Identification System (AIS) datasets from the vessel with weather hindcast data. The GBM model showed higher prediction accuracy for ship speed and fuel consumption than conventional pure Weather-Based Models (WBMs) or pure Black-Box Models (BBMs). Using a 57,000 DWT bulk carrier as the data collecting vessel, the study demonstrated the GBM's ability to forecast arrival time and provide weather routing, which should position the model as a flexible, accurate prediction tool applicable to vessels that do not have necessary sensor-collected data collected formally (Liu., et al., 2020).

Objectives

- 1) To evaluate the level of awareness of digital twins in the maritime industry.
- 2) To examine the ways digital twin solutions can be used to enable predictive ship maintenance and efficient port management, and thus address the congestion issues.
- 3) To investigate the use of digital twins in improving safety, efficiency, and sustainability in the maritime industry.

Formulation of Hypothesis

H1 (Alternate): The stakeholders in the maritime industry are highly aware of the digital twin technologies.

H2 (Alternate) Digital twin solutions play a critical role in predictive ship maintenance and efficient port management when addressing the problem of congestion.

H3 (Alternate) Digital twins technologies play an important role in increasing the safety, efficiency, and sustainability within the maritime industry.

Research Methodology

Research Design

This paper is devoted to the cognition of digital twin technologies in the field of maritime and their potential application to the digital innovations in the industry in the spheres of predictive maintenance, port management, and sustainability. Therefore, the study will follow a mixed-method research design that is both descriptive and exploratory in nature, thus making the adoption of the research approach practical and academically valid.

The undefined problem can be investigated with the help of the exploratory research design that aims at creating knowledge, generating patterns, and providing ideas on how to carry out further research. It is a versatile structure and tends to use qualitative research like literature reviews, focus groups, and interviews. A descriptive study strategy is the approach to describing the nature of behaviour or trend of a given population or phenomenon that takes a simpler approach of not altering one or more variables (Creswell et al. 2018). The

design used surveys, observation and case studies to provide answers to the questions of what, where, when, and how. (Babbie et al. 2020)

Sources of Data

Primary data is considered as the primary information obtained by use of a method like survey, interviews, experiment or even direct observation. Such data is particularly useful in the study of new phenomena, hypothesis testing, and determination of direct relationships between variables in the real world setting" (Sekaran and Bougie, 2016) The research study will involve the use of Google Forms Questionnaire to gather primary data among the target respondents. The questionnaire contained both close and open-ended questions to get the relevant information.

According to Smith (2020), secondary data may help a researcher utilize already collected information and provide a clear image of the trends and patterns in the industry without incurring the costs of primary data collection. There is a paradigm shift in the logistics and maritime industry, particularly with the rapid adoption of digital technologies like the drones, being integrated. It has been found that drones can revolutionize logistical tasks in supply chain management and operations by providing faster and efficient services.

Sampling Frame

A sampling frame explains the population that will be studied, in other words, it provides a description or list of a population where a sample will be picked. The precise and current frame is required to ensure representative sampling and results that might be extrapolated (Creswell 2014). The sampling frame of this study would consist of two lists, which will contain: Port officials and employees in India: This would have a database or a directory of all the people employed by port authority and other concerns in the other ports in India. This list ought to be representative enough to ensure that the population is well represented. List of Students and Professionals of Maritime Universities in India: This would be a list of contacts of students attending courses related to maritime (such as MBA) at the maritime universities in India, as well as professionals in the maritime industry that would be affiliated with such universities or professional organizations. This list would have to be generated based on college books, professional associations.

Sampling Technique

In this study the adoption of non-probability sampling methods is a means of sampling work since this is more convenient and less time-consuming. As a population, such approaches will enable selecting those individuals who are accessible, willing to participate, and fulfilling the targeted needs. It will conserve time and resources, especially when there is scarcity. Convenience Sampling: The researchers select individuals to reach or get in touch with. This technique is time-saving, less effort, and money-saving; this is the reason why it is commonly applied when the resources are scarce.

Sample Size

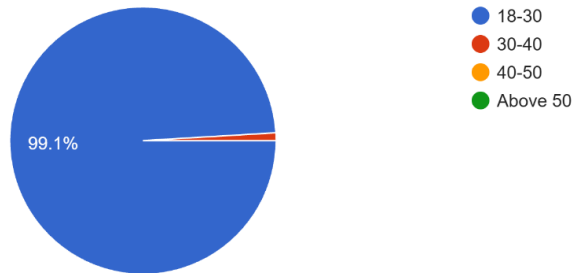
In the study, the sample size is 100 and above since it is regarded as providing good results that can be useful and it is not complicated to handle. Since it offers a fair level of practicality and reliability, a sample of about 100+ is commonly used in a study. It is not too big to be meaningful in terms of its discoveries and identification of patterns but too small to be too time-consuming, too expensive, and demanding. This renders it appropriate to simple quantitative research where the focus is to acquire generic information about a broader group of people.

Data Analysis And Interpretation

Demographic Data

Age

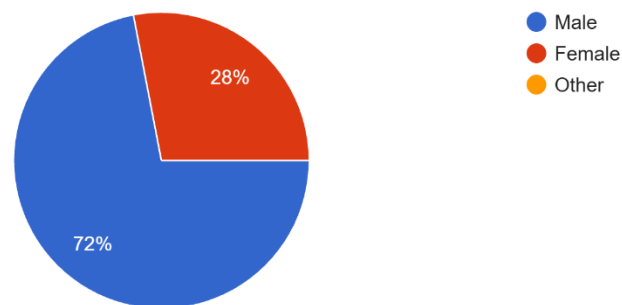
107 responses



1.1 Age share in Respondent Demography

Gender

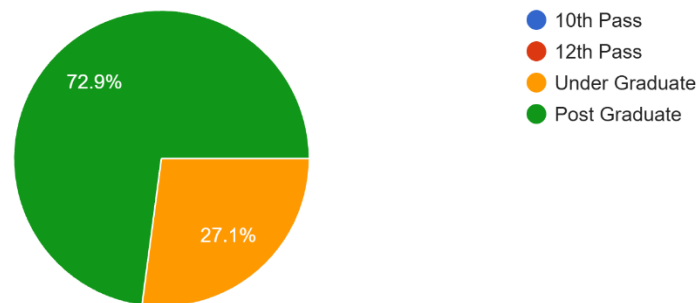
107 responses



1.2 Gender share in Respondent Demography

Qualification

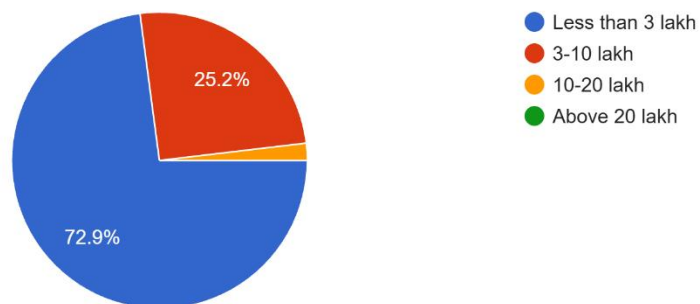
107 responses



1.4 Qualification share in Respondent Demography

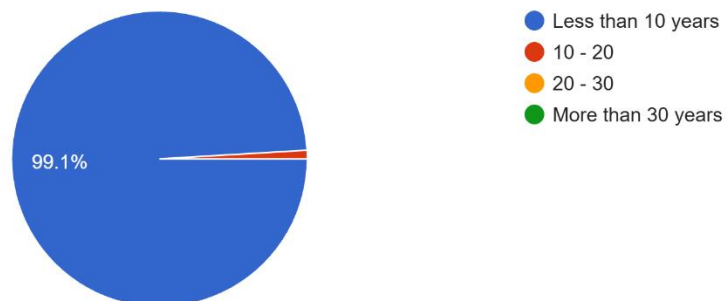
Annual Income

107 responses



Expeience

107 responses



1.5 Annual Income & Experience share in Respondent Demography

Discussion

To assess the awareness level of digital twin technologies in the maritime sector.

H1 Stakeholders in the maritime sector have significant awareness of digital Twin technologies.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Familiarity	81.936	106	.000	4.598	4.49	4.71
Knowledge	89.476	106	.000	4.505	4.40	4.60

The one-sample t-test results indicate that both familiarity and knowledge levels are significantly higher than the test value of zero ($p < 0.001$). This confirms that respondents possess a high degree of familiarity and knowledge, and the differences are statistically significant.

The Objective to analyse how digital twin solutions can support predictive ship maintenance and efficient port management, thereby tackling congestion challenges. H1 Digital twin solutions play a critical role in predictive ship maintenance and efficient port management when addressing the problem of congestion.

Type of analysis: ANOVA

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	70.524	2	35.262	58.306	.000 ^b
	Residual	62.897	104	.605		
	Total	133.421	106			

a. Dependent Variable: Digital Twin improves port efficiency / Congestion

b. Predictors: (Constant), Digital Twin improves forecasting accuracy, Digital Twin supports predictive ship maintenance

The one-way ANOVA results indicate that the significance value (p-value) is less than 0.05, which means there is a statistically significant difference in the level of awareness of Digital Twin technology among different respondent groups. Since the p-value is less than 0.05, the null hypothesis is rejected and the alternative hypothesis is accepted.

The objective is to study the role of digital twins in enhancing safety, efficiency, and sustainability in the maritime sector. H1 Digital twin technologies have a significant role in enhancing safety, efficiency, and sustainability in the maritime sector.

→ Correlations

[DataSet2]

		Correlations		
		Digital Twin Improves Safety in maritime operations	Digital Twin improves operational efficiency	Digital Twin supports sustainability in maritime sector
Digital Twin Improves Safety in maritime operations	Pearson Correlation	1	.728**	^b
	Sig. (2-tailed)		.000	.
	N	107	107	107
Digital Twin improves operational efficiency	Pearson Correlation	.728**	1	^b
	Sig. (2-tailed)	.000		.
	N	107	107	107
Digital Twin supports sustainability in maritime sector	Pearson Correlation	^b	^b	^b
	Sig. (2-tailed)	.	.	.
	N	107	107	107

Figure 1:

Correlation

The correlation analysis shown in figure 1 examined the relationship between Digital Twin improving safety in maritime operations, Digital Twin improving operational efficiency, and Digital Twin supporting sustainability in the maritime sector. There is a strong positive correlation between Digital Twin improving safety and Digital Twin improving operational efficiency.

Managerial Implication

The training programs, workshops, and seminars should be implemented by maritime organizations, educational institutions, and port authority to improve the practical knowledge and awareness of digital twin technology, in particular, among early-career professionals and students. The Digital Twin systems are to be incorporated with the existing terminal operating systems, vessel traffic management systems, and maintenance platforms by the port authority and shipping operators to enhance operational efficiency and monitoring of the real situation.

Predictive maintenance implementation for the Shipping companies need to use digital twin technology to ensure predictive maintenance gain more prominence since it reduces the number of equipment failures, lessens downtimes, decreases the maintenance expenses, and increases vessel safety. As a policy of support and investments, a digital twin would be supported by government agencies and marine regulators in terms of policy frameworks, financial incentives, and development of digital infrastructure, facilitating the smooth shift to smart and sustainable ports. In future research, it can investigate impediments preventing the adoption of digital twins, analysis of cost-benefits, and long-term effects on performance in various port sizes and shipping segments with bigger datasets and more sophisticated analysis methods.

Conclusion

The study concludes that digital twin technology has significant potential to enhance efficiency, safety, predictive maintenance, and sustainability in the Indian maritime sector. The findings show a positive level of awareness among stakeholders and strong support for the role of digital twins in improving port operations, reducing congestion, and lowering

operational risks. Statistical analysis confirms that digital twins can meaningfully contribute to predictive maintenance and operational performance.

Despite these benefits, challenges such as high costs, limited digital infrastructure, lack of skilled manpower, and cybersecurity risks continue to restrict large-scale adoption. Therefore, a phased implementation supported by training, policy initiatives, and investment in digital infrastructure is essential. With appropriate support, digital twin technology can play a key role in India's transition toward smart, efficient, and sustainable maritime operations.

The primary data was collected from a limited number of respondents, which is 107, due to time constraints and limited access to industry experts. This may not reflect the overall view of the entire maritime industry. The respondents might have given biased opinions because of their personal experiences or organizational policies, which will influence the findings. Some of the respondents were not very knowledgeable on technical aspects of drone operations, and this limited them in giving detailed answers. Primary data were taken in particular areas like Chennai, Kerala, Gujarat, and Kolkata, and thus the results may not be generalized to other areas where the technology adoption is not at the same rate.

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Awareness of Blockchain in the Indian Maritime Industry

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Abstract

Blockchain technology has become a disruptive digital innovation with the potential to significantly enhance transparency, efficiency, and security in international maritime activities. The maritime business, whose transactions cover close to 90 percent of international commerce, remains strongly rooted in the paper-based documentation systems, which results in the causes of operational delays, high administrative expenses, and the likelihood of fraud. Despite orchestrating successful paperless trade solutions globally using blockchain-based platforms like TradeLens, the uptake of such solutions in the maritime industry in India remains low. Among the most prevalent reasons identified in the current research is that maritime stakeholders lack awareness and understanding of blockchain. The paper will investigate the extent of the Indian maritime industry's knowledge of blockchain technology and its linkage to perceptions of barriers, intentions to adopt, and perceived benefits.

The primary data were gathered structured questionnaire administered to students, trainees, and professionals working in the maritime and shipping industry in India. In the study, awareness is a central variable in determining trust, cost perception, regulatory issues and adoption intention. It is likely that the findings will demonstrate that awareness of blockchain is quite low, especially its practical use in the maritime field. It is expected that the higher the awareness level, the more willingness to implement blockchain-based documentation systems and the stronger the belief in the positive outcome of the application like reduction of paperwork, prevention of fraud, and efficiency in the functioning. The work also adds to the literature by offering India specific empirical evidence and by describing the significance of awareness-building campaigns, training programs, and pilot projects for accelerating the adoption of blockchain technology in the maritime sector. The findings will provide the practical implications to policy makers, learning institutions and industry players with the intention of enhancing the digital transformation in the Indian maritime operations.

Keywords: Blockchain, Maritime Industry, Awareness, Digital Transformation, Paperless Trade, Smart Contracts

Introduction

The shipping industry is the mainstay of international trade, as almost 90 percent of the transportation of international goods occurs through the shipping industry. In the past, maritime operations have relied on voluminous documentation, including bills of lading, cargo manifests, customs declarations, and certificates of origin.

The operations of these documents have always been manual and were carried out through physical documents, a number of intermediaries and verification of the same. Even though it is a system that operated decades ago, it has been plagued with inefficiency given the rising volumes of trade and intricate supply chain. Documentation in paper form causes port delays, increases administrative expenses, work duplication, and susceptibility to fraud and loss of documents. Most of the maritime documentation platforms are centralized, fragmented, and rely on the trust among various parties, in spite of the introduction of digital systems. Such restrictions have resulted in a high demand for a safe, open and cooperative online system.

The blockchain technology provides a decentralised digital ledger, which is a solution to these challenges in as much as it records transactions in a safe and immutable manner. Blockchain enables interested parties to access verified data in real-time and removes the possibility of physical documentation and reconciliation. Blockchain may be implemented in the maritime sector in documentation management, cargo tracking, customs clearance, and automating payments by the use of smart contracts. The world has seen platforms like TradeLens by Maersk-IBM show that blockchain can help lessen paperwork and increase coordination and efficiency in operations.

Although the available literature recognizes the advantage of blockchain, there is limited empirical research that specifically looks at the level of awareness among the Indian maritime students, trainees, and professionals. Additionally, there is little quantitative research on the effect of awareness on perceived barriers, the desire to change, and perceived benefits in the maritime field.

Literature Review

The adoption of blockchain is a slow trend in India's maritime industry despite its potential. Point out that one of the greatest obstacles to blockchain uptake in the Indian environment is low awareness. According to their research, many Indian companies view blockchain as a technology of the future, and not the current operational technology. This picture leads to insufficient appreciation of practical benefits like transparency, efficiency as well as reduction of costs. The result is that low awareness leads to other impediments, such as regulatory uncertainty, non-investment and technical inability Kamble, et al. (2019).

This study discusses how information sharing in maritime supply chains could be realized through blockchain and discovered that demand-sharing benefits awareness is a significant factor that can affect the willingness to adopt. Companies with awareness of the strength of blockchain in facilitating data exchange in a secure and real-time environment are more likely to adopt it and have a better expectation when it comes to coordination and reduction of delays. Conversely, low awareness companies are still relying on old systems and are not aware of the long-term efficiency benefits of blockchain (Wu, et al., 2024).

In the Indian context they gave further evidence in their study in blockchain adoption in Indian SMEs to finance supply chains. Ignorance and training in their results show that these are the two most important barriers to adoption. Even companies that show interest in blockchain are not confident because they have poor exposure and no formal training and development programmes (Jaspreet Kaur et al., 2022).

According to the study, blockchain has the opportunities to enhance the management of ports and their logistics, the transparency of their documentation, and the resolution of maritime conflicts. Nevertheless, the research also reports a lack of awareness among professionals in the field of maritime law, port operators, and regulators, as well as in policy guidance. (Sapovadia, 2024). The Study compares blockchain's role in digital transformation across shipping companies. Finds that regions with higher awareness levels (Europe) adopt faster than those with low awareness (Asia/India). Concluding awareness is a competitive differentiator (Alzahrani, B., & Daim, T., 2021).

The study of models for blockchain-based information sharing between ports and carriers. Finds that when firms are aware of benefits, adoption intentions rise. Lack of awareness leads to resistance even when technology is available (Xiao, 2024).

Asian-focused study on blockchain adoption in maritime freight. Finds that awareness in Asia is lower than in Europe. Suggests that boosting awareness campaigns can help Asian countries, including India, close the gap (Alzahrani, 2024).

The study explores blockchain in maritime supply chains from a circular economy perspective. Shows that while blockchain can reduce waste and paperwork, low awareness among firms prevents large-scale use. Highlights education and pilot projects as solutions (Di Vaio, A., & Varriale, L. 2020).

All these studies indicate that awareness is the prerequisite of blockchain integration in the maritime industry in India.

Objectives

1. To determine the level of awareness and knowledge of blockchain technology among Indian maritime professionals and students.
2. To examine the major obstacles (trust, cost, technology, and regulation) that hinder the adoption of blockchain in Indian maritime Industry.
3. To determine whether the shipping companies, port authorities, and students are interested in adopting a blockchain-based documentation system in the future.
4. To evaluate the perceived benefits of blockchain in reducing paperwork, fraud, and operational delays in the Indian context.

Formulation of Hypothesis

H1 (Alternate): There is a relationship between respondents' age and their level of awareness of blockchain.

Objective 2: Barriers

H2 (Alternate): There is a relationship between respondents' awareness of blockchain and their perception of barriers

Objective 3: Willingness

H3 (Alternate): There is a positive relationship between awareness of blockchain and willingness to adopt blockchain-based documentation.

Objective 4: Perceived Benefits

H1 (Alternate): There is a positive relationship between awareness of blockchain and perceived benefits (reducing paperwork, preventing fraud, reducing delays).

Research Methodology

Research Design

This study adopts a descriptive and correlational research design.

The descriptive aspect will capture the current level of awareness, perceived barriers, willingness, and perceived benefits of blockchain among respondents.

The correlational aspect will test the relationships between awareness and other variables (barriers, willingness, and perceived benefits), and between respondents' background (students vs professionals) and their awareness.

A quantitative survey method using a structured questionnaire has been selected as it enables collection of measurable data from a defined sample within a limited time frame.

Sources of Data

Primary Data: Collected through a Google Form survey

Secondary Data: Collected from published review journals, articles, industry reports, and government publications related to blockchain adoption and awareness in the maritime industry.

Target Population

Element: Individuals who are students, trainees, or working professionals in or preparing for the maritime and shipping industry.

Sampling Unit: Each respondent from the maritime domain (student, trainee, or professional) & others.

Extent: Respondents are located in (Ahmedabad, Gandhinagar, Mumbai,{India}), as the study focuses on checking small-scale research (through students) about the awareness levels in the maritime context.

Time: Cross-sectional data will be collected within a fixed period (approx. 3-4 months) during the academic semester.

Sampling Frame

The sampling frame will be made of: College departments, training institutions in maritime and shipping.

Sampling Technique

A purposive sampling method that is non-probability will be applied.

The respondents will be chosen according to the revelation to the maritime sphere (students, trainees, professionals) as well as any other. This approach is suited to such a small-scale exploratory study that aims at awareness in a specific area as opposed to the general population estimates.

Sample Size

A sample size of approximately 100 respondents will be targeted to provide sufficient data for correlation and chi-square analysis while remaining feasible within the study's scope. This size is adequate for a small-scale academic study and aligns with the descriptive and correlational research design.

Although the current literature recognizes the advantages of blockchain, a narrow research has been conducted on the level of awareness of Indian maritime students, trainees, and professionals. Moreover, few studies quantitatively examine how awareness influences perceived barriers, willingness to adopt, and perceived benefits within the maritime domain.

Data Analysis

Relation between Age & Awareness about Blockchain Usage in the Maritime Industry

OBSERVED VALUE

Row Labels	I know that blockchain can be applied in the maritime industry.	Are you aware of the concept of blockchain technology	Sum of I understand the difference between traditional documentation and blockchain-based documentation.	Count of Information about blockchain in the maritime industry is easily available to me.	Grand total
21-25	129	66	145	66	406
26-30	64	32	63	32	191
below 20	9	3	8	3	23
Grand Total	202	101	216	101	620

EXPECTED VALUE = ROW TOTAL * COLUMN TOTAL / GRAND TOTAL

Row Labels	Sum of I know that blockchain can be applied in the maritime industry.	Count of Are you aware of the concept of blockchain technology	Sum of I understand the difference between traditional documentation and blockchain based documentation.	Count of Information about blockchain in maritime industry is easily available to me.
21-25	132.2774194	66.13870968	141.4451613	66.13870968
26-30	62.22903226	31.11451613	66.54193548	31.11451613
below 20	7.493548387	3.746774194	8.012903226	3.746774194

(O-E)²/E

Row Labels	Sum of I know that blockchain can be applied in the maritime industry.	Count of Are you aware of the concept of blockchain technology	Sum of I understand the difference between traditional documentation and blockchain based documentation.	Count of information about blockchain in maritime industry is easily available to me.

Awareness of Blockchain in the Indian Maritime Industry

21-25	0.081204167	59.7462793	1.094997087	59.7462793
26-30	71.6444073	307.9452662	58.62483252	307.9452662
below 20	1970.203837	4187.167351	1826.788266	4187.167351

X2	13038.15534
df	1
p-value	0

Chi square test for purpose of finding a connection between age and awareness about Blockchain Usage in the Maritime Industry

Objective 1: Awareness

H1 (Alternate) There is a relationship between respondents' age and their level of awareness of blockchain. P value > 0.05 accept, P < 0.05, Thus, we reject the Null Hypothesis. It means that there is a relationship between respondents' age and their level of awareness of blockchain.

Relationship between respondents' awareness of blockchain and their perception of barriers (trust, cost, regulation, technology).

OBSERVED VALUE					
Row Labels	Count of Lack of trust in blockchain systems is a major barrier for adoption.	Count of High cost of implementation discourages blockchain use	Count of lack of training and awareness program is a Challenge for adoption of blockchain technology	Count of Lack of Technical knowledge is a barrier to using blockchain	Grand total
21-25	66	66	66	66	264
26-30	32	32	32	32	128
below 20	3	3	3	3	12
Grand Total	101	101	101	101	404

OBSERVED VALUE				
Row Labels	Lack count of trust in blockchain systems is a major barrier for adoption.	Count of High cost of implementation discourages blockchain use	Count of lack of training and awareness program is a Challenge for adoption of blockchain technology	Count of Lack of Technical knowledge is a barrier to using blockchain
21-25	66	66	66	66
26-30	32	32	32	32
below 20	3	3	3	3

(O-E) ² /E				
Row Labels	Count of Lack of trust in blockchain systems is a major barrier for adoption.	Count of High cost of implementation discourages blockchain use	Count of lack of training and awareness program is a Challenge for adoption of blockchain technology	Count of Lack of Technical knowledge is a barrier to using blockchain
21-25	0	0	0	0
26-30	36.125	36.125	36.125	36.125
below 20	1323	1323	1323	1323

X2	5436.5
df	1
p-value	0

OBSERVED VALUE			
Row Labels	Count of I am willing to adopt blockchain-based systems if my institution/company provides it.	Count of I would encourage others to adopt blockchain in maritime documentation	Grand total
21-25	66	66	132
26-30	32	32	64
below 20	3	3	6
Grand Total	101	101	202

EXPECTED VALUE = ROW TOTAL * COLUMN TOTAL / GRAND TOTAL		
Row Labels	Count of I am willing to adopt blockchain-based systems if my institution/company provides it.	Count of I would encourage others to adopt blockchain in maritime documentation
21-25	66	66
26-30	32	32
below 20	3	3

(O-E) ² /E		
Row Labels	Count of I am willing to adopt blockchain-based systems if my institution/company provides it.	Count of I would encourage others to adopt blockchain in maritime documentation
21-25	0	0
26-30	36.125	36.125
below 20	1323	1323

X2	2718.25
df	1
p-value	0

Chi-square test for the purpose of finding a connection between awareness & reasons for barriers to using Blockchain in the Maritime Industry

Objective 2: Barriers

H1 There is a relationship between respondents' awareness of blockchain and their perception of barriers $P \text{ value} < 0.05$ reject H_0 , $P \text{ value} > 0.05$ accept H_0 **P value:** $0 < P < 0.05$, Thus, we reject the Null Hypothesis. It means that there is a relationship between respondents' awareness of blockchain and their perception of barriers

Relationship between respondents' awareness of blockchain and their perception of barriers (trust, cost, regulation, technology).

Chi-square test for the purpose of finding a connection between awareness of blockchain and willingness to adopt blockchain-based documentation.

Objective 3: Willingness

H1 (Alternate) There is a positive relationship between awareness of blockchain and willingness to adopt blockchain-based documentation.

$P \text{ value} < 0.05$ reject H_0 , $P \text{ value} > 0.05$ accept H_0 , **P value:** $0 < P < 0.05$, Thus, we reject the Null Hypothesis. It means that there is a positive relationship between awareness of blockchain and willingness to adopt blockchain-based documentation.

Relationship between awareness of blockchain and perceived benefits (paperwork reduction, fraud prevention, delay reduction).

OBSERVED VALUE			
Row Labels	Count of Blockchain can significantly reduce paperwork in maritime shipping	Count of Blockchain will improve transparency & trust in maritime transaction	Grand Total
21-25	66	66	132
26-30	32	32	64
below 20	3	3	6
Grand Total	101	101	202

EXPECTED VALUE = ROW TOTAL * COLUMN TOTAL / GRAND TOTAL		
Row Labels	Count of Blockchain can significantly reduce paperwork in maritime shipping	Count of Blockchain will improve transparency & trust in maritime transaction
21-25	66	66
26-30	32	32
below 20	3	3

(O-E) ² /E		
Row Labels	Count of Blockchain can significantly reduce paperwork in maritime shipping	Count of Blockchain will improve transparency & trust in maritime transaction
21-25	0	0
26-30	36.125	36.125
below 20	1323	1323

X ²	2718.25
df	1
p-value	0

Chi-square test for the purpose of finding a connection between awareness of blockchain and willingness to adopt blockchain-based documentation.

Objective 4: Perceived Benefits

H1 (Alternate) There is a positive relationship between awareness of blockchain and perceived benefits (paperwork reduction, fraud prevention, delay reduction). P value < 0.05 reject H₀, P value > 0.05 accept H₀, **P value:** 0, P < 0.05, Thus, we reject the Null Hypothesis. It means that there is a positive relationship between awareness of blockchain and perceived benefits (paperwork reduction, fraud prevention, delay reduction).

Discussion

The research brings about a number of significant discoveries about awareness, barriers, willingness and perceived benefits of blockchain technology in the Indian maritime industry.

Most of the respondents were found to have fundamental knowledge of blockchain technology with more than 70% of them showing their knowledge of blockchain technology and how it is used in maritime documentation. The respondents of the 21-25 and 26-30 age groups also showed a higher awareness and the chi-square test showed that there is a significant relationship between age and awareness and this resulted to the rejection of the null hypothesis of Objective 1.

The results also indicate the high level of correlation between awareness and perceived barriers. The lack of awareness, the high cost of implementation, a lack of technical knowledge, and a lack of training programs are also major obstacles among respondents with high awareness of blockchain. The chi-square test for Objective 2 showed that perceptions of the barriers depend to a great extent on awareness.

A positive adoption trend was witnessed. Most people said that they were willing to implement blockchain-based systems if their institution or organisation offered them, and

most were also open to motivating others. The statistical findings were in support of Objective 3 in that there was a significant positive relationship between awareness and willingness to adopt. Lastly, the respondents mostly concurred that blockchain would reduce paperwork and enhance transparency and trust. The chi-square test verified the significance of the relationship between awareness and perceived benefits, supporting Objective 4.

The results of this research align with the literature review's trends, which highlight awareness as the core driver of blockchain implementation in the maritime sector. Just as previous investigations have indicated low awareness as the basis of the challenge, the current research indicates that better-aware respondents are in a better position to identify the positive and negative aspects of blockchain implementation.

The strong correlation between age and awareness implies that younger respondents, especially those within the 21-25 age bracket, are exposed more to the emerging digital technologies in learning and training settings. This confirms previous research that younger professionals and students are more open to digital transformation initiatives.

The remarkable correlation between awareness and perceived barriers suggests that educated respondents cannot dismiss blockchain outright but must critically assess practical issues such as cost, confidence, and technical preparedness. This result indicates that the literature has given importance to knowledge gaps that increase resistance to adoption.

Moreover, the significant correlation between knowledge and readiness to implement indicates that the more people know about the concept, the more willing they are to change. The more respondents realised that blockchain could help them reduce paperwork and enhance transparency, the greater their adoption intent. In general, it has been argued that awareness may not remove barriers but only allow informed acceptance, which is why it is argued that education and exposure are the necessary antecedents to the implementation of blockchain in the Indian maritime industry.

Conclusion

This paper has reviewed the knowledge of blockchain technology among the Indian maritime industry and its association with perceived obstacles, intention to use, and perceived value. The results provide a solid explanation of awareness as the strongest factor in determining respondents' attitudes towards adopting blockchain.

Whereas blockchain has been discussed as a disruptive technology in maritime documentation, the findings revealed that awareness is not evenly distributed and is instead concentrated among younger participants and those already participating in an academic or educational setting.

The statistical result proved that there is a strong correlation between age and awareness, which means that younger respondents have more knowledge of blockchain-related concepts. This implies that institutions of learning are important in exposing the future maritime personnel to emerging technologies.

Nevertheless, awareness does not necessarily lead to adoption, as respondents also reported significant obstacles to implementing EMRs, including a lack of trust, the high cost of implementation, a lack of technical skills, and inadequate training. Notably, the research shows that awareness positively influences the desire to implement blockchain-based systems. The respondents who understood the uses and benefits of blockchain found it more acceptable to replace paper-based records and encourage others to adopt digital records. This brings out the role of awareness as a driver of behavioural intention and not a predictor of actual implementation. The fact that the perceived benefits of the study are as follows: the decrease in paperwork, the increase in the transparency level, and the increase in the level of trust, speaks in favor of the relevance of blockchain to the solution of the long-term

inefficiencies of maritime operations. The awareness and perceived benefit are closely correlated and it shows that more informed stakeholders can value the operational value of blockchain. This observation supports the idea that awareness-induction programs should be structured rather than one-sided technological programs.

Altogether, the research provides significant empirical data to the Indian maritime environment through the connection of awareness and critical variables of adoption. It points out that digitalization of operations in the maritime environment cannot be carried out by the use of technology. Rather, it needs to make parallel investments in education, training, and awareness-building programs.

To ensure that the gap between potential and practice is bridged, policymakers, port authorities, and maritime institutions should focus on capacity building, pilot projects, and exposure-based learning.

To sum up, a lack of awareness and readiness, rather than interest, is among the forces limiting the adoption of blockchain in the Indian maritime industry. Enhancing awareness is thus a tactical starting point for building confidence, lessening opposition, and enabling a more seamless migration to secure, transparent, and efficient maritime record-keeping systems.

Although this study offers some useful information, it has several limitations that need to be noted. First, the sample size was small (around 100 respondents), limiting the ability to generalise to the entire Indian maritime industry. Second, it is possible that purposive sampling, which was non-probability, could have caused selection bias, as the respondents were mainly students, trainees, and early-career professionals, while those in senior industry positions and policymakers were underrepresented. Third, the research relied on self-reported data collected via a structured questionnaire, which could be affected by subjective interpretation or social desirability bias. Also, it focused on awareness and perceptions rather than real experiences of implementing it, i.e., the results reflect the intention rather than the actual implementation outcomes. Finally, the research is cross-sectional, capturing perceptions at one point in time rather than changes in awareness or attitudes as blockchain usage evolves.

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Digital Transformation in Maritime Logistics: Examining the Role of Blockchain in Gujarat

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Abstract

This study focuses on Gujarat's maritime logistics industry's current level of digitalization, with an emphasis on how blockchain technology is changing conventional logistics procedures. This study evaluates improvements in transparency, security, efficiency, and traceability by contrasting blockchain-enabled digital frameworks with legacy paper-based systems. The study examines early adoption patterns, industry practices, and obstacles encountered by ports, freight forwarders, and customs house agents using a qualitative research methodology. According to the research, blockchain provides a "single version of truth," greatly lowering manual inefficiencies, fraud, and disputes. Additionally, the study highlights blockchain's potential role in supporting paperless trade initiatives, digital bills of lading, and smart contract-enabled logistics execution, which collectively reduce administrative burden and enhance cargo visibility throughout the supply chain lifecycle. The findings contribute to the growing discourse on digital port ecosystems by presenting Gujarat as an emerging regional case for blockchain-enabled maritime transformation in developing economies.

This research further highlights that successful blockchain implementation extends beyond technological deployment and requires regulatory alignment, workforce digital capability, and collaborative governance frameworks. By examining adoption challenges within an emerging maritime economy, the study provides insights into how regional logistics ecosystems can transition toward transparent, efficient, and technology-enabled maritime

Keywords: Digital Transformation, Maritime Logistics, Blockchain Technology, Supply Chain Transparency, Logistics Efficiency

Introduction

The maritime industry, which has traditionally been characterised by fragmented communication and paper-based documentation, is undergoing a paradigm shift driven by digital technologies. Among these, "blockchain" has emerged as a revolutionary tool that promises increased security, transparency, and efficiency in maritime logistics. With the expansion of global trade and the complexity of supply chains, stakeholders now need to share data securely and in an impenetrable way. Blockchain's decentralized and unchangeable ledger system can solve a number of persistent issues in maritime logistics, such as document fraud, a lack of visibility, and sluggish cargo processing.

The growing complexity of international maritime supply chains has intensified the requirement for secure, interoperable, and digitally integrated logistics systems capable of supporting real-time information exchange. Maritime logistics operations traditionally involve extensive documentation processes such as bills of lading, customs declarations, cargo manifests, and compliance certificates, which are often processed through disconnected systems. Such fragmentation results in delays, increased administrative costs, and reduced operational transparency. Blockchain technology introduces a decentralized architecture that enables synchronized data sharing among stakeholders while maintaining data integrity and auditability across the logistics network.

Furthermore, blockchain facilitates process automation through smart contracts, enabling conditional execution of logistics activities such as cargo release authorization, payment settlement, and compliance verification. This automation reduces reliance on manual verification procedures and minimizes operational bottlenecks across port and shipping operations. The technology also strengthens supply chain resilience by ensuring secure data storage and minimizing risks associated with document manipulation, cyber threats, and information asymmetry.

From a strategic perspective, blockchain adoption contributes to the development of digitally connected port ecosystems by enhancing collaboration among public and private stakeholders. The study evaluates how blockchain-driven platforms can support trade facilitation initiatives, improve stakeholder coordination, and enable paperless maritime trade environments aligned with global digital shipping standards. Particular emphasis is placed on understanding stakeholder perception, organizational preparedness, and institutional support mechanisms influencing technology adoption within Gujarat's maritime logistics sector.

Keyword "blockchain technology," a single version of the truth, is accessible to a variety of stakeholders, including customs, port authorities, freight forwarders, and shipping lines. Blockchain transactions reduce disputes and increase operational trust because they are transparent, time-stamped, and unchangeable. In the maritime industry, this leads to decreased documentation errors, real-time cargo tracking, and accelerated clearance processes. One of the most well-known applications is "TradeLens," a blockchain-based platform developed by IBM and Maersk. TradeLens facilitates safe information sharing across the global shipping ecosystem and can reduce shipment transit times by up to 40%.

Despite the potential, the "current state of blockchain adoption in maritime logistics" is still in its early stages. Many ports and shipping companies are testing various use cases in pilot or exploratory stages, including automated customs compliance, smart contracts, and digital bills of lading (e-BL). For instance, Singapore and the Port of Rotterdam have begun testing blockchain technology for container tracking and trade finance. However, there is currently no globally accepted framework for applying blockchain technology to maritime logistics.

However, because of high implementation costs, unclear regulations, and opposition to legacy systems, adoption in Gujarat is still in its early or pilot stages. In order to improve blockchain adoption and fortify digital transformation in the maritime logistics industry, the study ends with useful, policy-level recommendations. Gujarat handles almost 40% of the nation's total cargo throughput, making it a crucial component of India's maritime trade. The state has become a logistics hub for both domestic and foreign trade thanks to its major ports, which include Mundra, Kandla (Deendayal Port), Pipavav, and Hazira. Gujarat is a prime example for researching digital transformation in maritime logistics since the Gujarat Maritime Board (GMB) has aggressively supported port-led industrialization. But even with sophisticated physical infrastructure, documentation procedures and information flows are still dispersed, underscoring the need for digital solutions like blockchain.

The rapid evolution of global trade networks and increasing demand for supply chain resilience have accelerated the need for digital transformation within maritime logistics ecosystems. Traditional maritime operations depend heavily on fragmented documentation systems involving multiple intermediaries, resulting in operational inefficiencies, limited visibility, and increased transaction risks. Blockchain technology has emerged as a transformative digital infrastructure capable of enabling decentralised data exchange, secure transaction validation, and automated process execution across geographically dispersed stakeholders.

This study further investigates blockchain adoption from an institutional and operational readiness perspective by examining technological awareness, organisational capability, and

regulatory preparedness among maritime stakeholders in Gujarat. By integrating insights from port authorities, logistics firms, and freight intermediaries, the research evaluates how blockchain contributes not only to operational efficiency but also to strategic competitiveness and sustainable logistics governance.

One of the main benefits that blockchain provides to maritime operations is its ability to provide “real-time visibility,” or traceability. This improves inventory management and strengthens risk-mitigation strategies. That also allows for “smart contracts,” or self-executing agreements with predefined terms, to automate insurance claims, cargo releases and payment triggers. These characteristics work to build mutual trust between parties engaged in a transaction, reducing expenditures and administrative heads.

But the “adoption of blockchain” faces a number of barriers. Common barriers to adopting these technologies include considerable start-ups implementation costs, incompatibility with existing legacy systems, and organizational resistance to change.

Additionally, data privacy, governance and the legal enforceability of blockchain records remain milestone barriers to scale. Additionally, the global nature of the maritime logistics process is yet another factor that adds complexity to adoption, as cross-border collaboration and standardization of protocols are necessary for blockchain implementation success.

The maritime logistics industry forms the backbone of international trade, facilitating nearly 80–90% of global merchandise transportation by volume. With increasing globalization, supply chains have become highly interconnected and data-intensive, requiring seamless coordination among shipping lines, port operators, customs authorities, freight forwarders, and regulatory institutions. However, the industry continues to face structural inefficiencies arising from siloed information systems and lack of standardized digital communication platforms. These challenges have intensified the urgency for adopting digital technologies capable of improving coordination, transparency, and operational responsiveness.

Digital transformation within maritime logistics is therefore no longer limited to automation but represents a systemic shift toward data-driven decision-making and integrated platform ecosystems. Technologies such as Artificial Intelligence, Internet of Things (IoT), Big Data analytics, and Blockchain collectively enable the transition toward smart ports and intelligent logistics networks.

Beyond technological advancement, blockchain represents an institutional innovation that reshapes trust mechanisms within maritime trade. Traditionally, trust in logistics transactions relies on centralised authorities and manual verification processes. Blockchain replaces this dependency by enabling distributed consensus mechanisms, ensuring that transaction records remain immutable and verifiable without intermediary intervention.

This transformation significantly reduces coordination costs while strengthening accountability among stakeholders. In maritime logistics, where multiple parties operate across jurisdictions, blockchain-based systems provide enhanced governance structures that can minimise disputes over cargo ownership, document authenticity, and shipment status verification.

India’s ambition to become a global logistics hub, through initiatives such as port-led development and trade facilitation reforms, has heightened the focus on maritime digitalisation. Despite infrastructural advancements under national maritime modernisation programs, procedural inefficiencies and documentation complexities continue to affect cargo turnaround time and logistics performance.

Gujarat, accounting for a substantial share of India's port cargo handling capacity, presents a unique ecosystem combining advanced private ports, industrial corridors, and export-oriented logistics activity. The presence of technologically progressive ports creates favorable conditions for experimenting with blockchain-enabled logistics solutions. However, disparities in technological readiness among stakeholders highlight the necessity of examining adoption challenges at a regional level.

This research gains significance by bridging the gap between technological potential and practical implementation within an emerging maritime economy. While global studies predominantly examine blockchain adoption in technologically mature ports, limited empirical evidence exists regarding developing regional ecosystems where institutional readiness, policy frameworks, and stakeholder coordination play a decisive role. By focusing on Gujarat's maritime logistics sector, the study contributes localized insights into digital transformation pathways applicable to similar developing maritime regions.

Indian maritime logistics continues to face challenges such as procedural delays, lack of end-to-end visibility, and high transaction costs due to reliance on manual documentation. According to industry reports, documentation-related delays alone can increase logistics costs by 20–25%. As India aims to reduce logistics costs to 8% of GDP, aligning with global benchmarks, digital technologies such as blockchain become critical enablers. Blockchain's ability to integrate multiple stakeholders on a single trusted platform aligns with India's broader digital trade ambition.

The Indian maritime logistics sector plays a vital role in facilitating international trade and economic development, yet it continues to experience structural inefficiencies arising from fragmented operational systems and limited technological integration. Despite significant investments in port infrastructure modernisation, operational processes across ports, customs authorities, shipping lines, freight forwarders, and inland logistics providers remain largely dependent on manual coordination and repetitive documentation procedures. These inefficiencies contribute to higher logistics costs, prolonged cargo dwell time, and reduced global competitiveness.

Digital transformation has therefore become a strategic necessity rather than an operational choice for India's maritime ecosystem. The increasing volume of containerised trade, rising customer expectations for real-time shipment visibility, and growing pressure to comply with international trade standards demand integrated digital platforms capable of seamless information exchange. Traditional information systems often operate in isolation, resulting in duplication of data entry, lack of interoperability, and delays in cargo clearance processes. Adoption of advanced digital technologies can enable synchronised communication among stakeholders and significantly enhance supply chain responsiveness.

In this context, blockchain technology emerges as a foundational enabler capable of integrating multiple stakeholders onto a trusted digital platform, thereby supporting India's transition toward efficient, transparent, and globally competitive maritime logistics operations.

Gujarat occupies a strategically significant position within India's maritime economy, handling a substantial share of the nation's total cargo throughput through both major and non-major ports. The state's extensive coastline, strong industrial base, and export-oriented manufacturing clusters have positioned it as a critical gateway for international trade. Ports such as Mundra, Deendayal (Kandla), Pipavav, Dahej, and Hazira collectively support containerised cargo, bulk commodities, petroleum products, and industrial shipments connecting India to global markets. However, the increasing scale and complexity of cargo movement have amplified operational and documentation challenges across Gujarat's maritime logistics ecosystem.

Despite advanced port infrastructure and private sector participation, logistics coordination among stakeholders in Gujarat often remains fragmented. Freight forwarders, customs authorities, port operators, shipping agents, transporters, and warehouse operators frequently rely on independent information systems that lack interoperability. This results in duplication of documentation, delays in cargo clearance, and limited real-time visibility across supply chain stages. Manual verification processes continue to slow decision-making, particularly during customs clearance, cargo release authorisation, and inter-agency coordination.

The rapid expansion of industrial corridors such as the Delhi–Mumbai Industrial Corridor (DMIC) and Special Economic Zones (SEZs) within Gujarat has further increased cargo volumes, necessitating digitally integrated logistics operations. As trade volumes grow, traditional paper-based systems struggle to manage documentation accuracy, compliance verification, and stakeholder communication efficiently. Digital transformation, therefore, becomes essential to ensure scalable, transparent, and resilient maritime logistics operations capable of supporting future trade demand.

Moreover, Gujarat's ambition to emerge as a global logistics and transshipment hub requires the adoption of intelligent digital platforms that enhance operational efficiency and stakeholder trust. Blockchain-enabled systems can significantly benefit Gujarat's port ecosystem by enabling secure information exchange, digital bills of lading, automated compliance processes, and real-time cargo tracking. Such systems reduce administrative dependency while improving coordination among public authorities and private logistics participants.

Therefore, digital transformation in Gujarat's maritime logistics sector is not merely a technological modernisation initiative but a strategic requirement for sustaining trade competitiveness, improving turnaround efficiency, and strengthening global supply chain integration. Adoption of blockchain technology provides Gujarat with an opportunity to transition toward a unified, transparent, and digitally interconnected maritime ecosystem capable of supporting long-term economic growth.

Literature Review

This study examines the role of blockchain technology in improving transparency and trust within supply chain and logistics operations. The study explains that traditional logistics systems suffer from fragmented information sharing, documentation inefficiencies, and risks of fraud. Blockchain technology enables decentralized and immutable record keeping, allowing stakeholders to access verified information in real time. The research highlights that blockchain reduces dependency on intermediaries and enhances operational coordination through smart contracts and automated verification mechanisms. Despite these advantages, challenges such as scalability limitations and integration with legacy systems continue to restrict large-scale adoption (Kshetri, 2018).

This paper analysed blockchain adoption readiness among Indian MSMEs using technology adoption frameworks. The study identifies organizational readiness, technological awareness, implementation cost, and regulatory clarity as key determinants influencing adoption decisions (Cithal et al. 2019). The findings reveal that although blockchain enhances transaction security and operational transparency, MSMEs face major constraints such as financial limitations, a lack of skilled workforce, and insufficient digital infrastructure. The authors emphasize the need for policy support and training initiatives to encourage adoption in developing economies (Mittal et. al., 2022).

This paper discussed blockchain technology as a decentralized governance mechanism capable of establishing trust without centralized authorities. The study explains that blockchain-based systems rely on consensus mechanisms that enhance transparency,

accountability, and transaction reliability (Vital et. al.,2021). The blockchain implementation requires institutional coordination, regulatory alignment, and governance frameworks rather than purely technological advancement. Issues related to legal enforceability, interoperability, and privacy remain major implementation concerns (Werbach, 2018). The comprehensive framework explaining blockchain's role in digital transformation across industrial ecosystems. The study highlights blockchain's capability to ensure data integrity, enhance cybersecurity, and streamline multi-stakeholder transactions. The authors demonstrate that blockchain integration improves operational efficiency through automation and secure data exchange. However, organizational resistance, technological complexity, and scalability challenges are identified as barriers to implementation (Casino, Dasaklis, and Patsakis, 2019). The global transition from manual to automated processes in logistics. It identifies key disruptive technologies such as Blockchain, IoT, AI, and Big Data that are being implemented across various regions, including Taiwan, China, and Europe, to improve supply chain productivity and minimize costs. The potential of blockchain to impact various industries by increasing transparency, security, and traceability. However, it notes that for blockchain to move beyond "proof-of-concept" projects into mainstream deployment, significant challenges regarding scalability and interoperability must first be resolved (Siddhartha Nigam & Wali ,2026)

Focusing on the project *Mare Nostrum*, this study surveys 202 Tunisian and Italian fishermen to evaluate their intention to adopt blockchain. Using the Technology Acceptance Model (TAM), the researchers found that perceived usefulness directly impacts adoption attitudes, while social influence positively affects both perceived usefulness and behavioural intention. Interestingly, factors like age and educational qualification did not significantly alter these relationships (Souha Douzi, et al., 2026). The determinants for implementing blockchain in maritime freight companies, where data exchange is often difficult due to the high number of involved parties. The study identifies government policies, firm size, and perceived cost of investment as the most critical factors influencing successful adoption (Singh, et al., 2024). The uses a hybrid approach (SEM and ANN) to analyze factors influencing blockchain deployment in the sustainable maritime freight industry. It concludes that initial investment costs, trust in digital technology, and sustainability-enabled digital training are the most essential factors for decision-makers and policymakers to consider when constructing efficient transportation systems (Singh et. al., 2024). To address specific problems in the pharmaceutical supply chain, particularly regarding effectiveness and sustainability. While the technology is noted to be in its infancy, researchers highlight its potential to support and resolve complex issues within the sector (Shaker,2020).

A review of existing literature reveals that while extensive research has been conducted on blockchain adoption in global maritime logistics, particularly in developed economies, limited studies focus on regional or state-level adoption in India. Most studies emphasize technological benefits and adoption challenges but lack empirical insights into policy, institutional readiness, and stakeholder coordination in emerging economies. Furthermore, Gujarat-specific studies examining blockchain implementation within port ecosystems remain scarce. This research addresses these gaps by offering a contextualised analysis of blockchain adoption in Gujarat's maritime logistics sector.

Objectives

1. To analyse the effect of blockchain technology on improving transparency and information sharing among maritime logistics stakeholders.
2. To evaluate the role of blockchain technology in enhancing operational efficiency and reducing documentation delays in maritime logistics operations.

Formulation of Hypothesis

H1: There is significant improvement in the maritime inter-organizational operations after implementation of blockchain technology

Research Methodology

Research Design

Based on the research proposal, a qualitative research design would be most appropriate. This approach is well-suited for investigating complex, nuanced topics like the adoption of new technology and the challenges associated with it. The use of interviews as the primary data collection method suggests an exploratory and descriptive study. The goal is to gain in-depth insights and understand the perspectives of individuals within the maritime logistics sector rather than to test a hypothesis with quantitative data.

Target Population

Individuals with professional experience in the maritime logistics industry, specifically those involved with technology, supply chain management, or operational roles. The individuals who will be interviewed, such as freight forwarders, port authorities, customs officials, and IT managers.

Sampling Frame

The sampling frame would be a list or a representation of the individuals who meet the criteria for the target population. Given the use of a snowball sampling technique, a complete list is not required. The initial contacts (the "seeds") for the snowball sample will form the basis of the sampling frame. This could include key individuals from companies mentioned in the literature review, or professionals with public profiles on platforms like LinkedIn.

Sampling Technique

The proposed sampling technique is non-probability snowball sampling. This technique is suitable when the target population is difficult to access or identify. It relies on referrals from initial participants to find other potential interviewees. This method is particularly effective for this topic because individuals knowledgeable about blockchain in maritime logistics are likely to be part of a professional network and can refer the researcher to others with similar expertise.

Sample Size

The planned sample size is 5-10 interviews. This size is typical for a qualitative study using snowball sampling and is sufficient for in-depth interviews. A small sample size enables detailed exploration of each participant's experiences and perspectives, which is crucial in qualitative research.

Sources of Data

This would be collected through semi-structured interviews. This method allows for a flexible conversation, enabling the researcher to explore unexpected themes while ensuring all key topics related to the research objectives, like transparency, security, and adoption, are covered. This includes the existing literature on blockchain in maritime logistics, such as academic papers, industry reports, and case studies. (e.g., Trade Lens, etc.). The proposal has already laid a foundation for this by referencing sources.

Data Analysis

The analysis is based on a comparison between the current (legacy) system and the blockchain-enabled system within maritime logistics operations in Gujarat.

- Documentation: Legacy systems rely heavily on paper-based documentation, leading to duplication, delays, and errors. Blockchain introduces a digital, unified, and tamper-proof record system.
- Transparency: The existing system provides low visibility and limited tracking capabilities. Blockchain enables real-time visibility and traceability across stakeholders.
- Security: Traditional systems are vulnerable to fraud and unauthorized changes. Blockchain's immutable and time-stamped records significantly enhance data security.
- Operational Processes: Manual verification and slow clearance dominate current practices, whereas blockchain enables automation through smart contracts.

The analysis also highlights early-stage adoption in Gujarat, where major players are exploring digital-first approaches, but widespread integration remains limited. Key barriers identified include infrastructure costs, lack of regulatory clarity, and organizational resistance to the technological aspect.

T-Test of Responses

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Manual verification slows cargo clearance processes.	75	2.09	1.243	.144
Are you aware about Blockchain?	75	1.35	.762	.088
Blockchain technology can significantly improve supply chain transparency.	75	2.39	1.102	.127
High implementation cost is a major barrier to blockchain adoption.	75	2.41	.988	.114

One-Sample Test						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Manual verification slows cargo clearance processes.	14.584	74	.000	2.093	1.81	2.38
Are you aware about Blockchain?	15.302	74	.000	1.347	1.17	1.52
Blockchain technology can significantly improve supply chain transparency.	18.764	74	.000	2.387	2.13	2.64
High implementation cost is a major barrier to blockchain adoption.	21.161	74	.000	2.413	2.19	2.64

SINCE THE P-VALUE OF IS 0.000 WHICH IS LESS THAN ALPHA-VALUE 0.05.
THEREFORE, NULL HYPOTHESIS IS REJECTED AND ALTERNATE ACCEPTED. SO WE CONCLUDE THAT THERE IS A SIGNIFICANT DIFFERENCE IN BLOCKCHAIN TECHNOLOGY.

A one-sample t-test was conducted to examine the perceptions of maritime logistics stakeholders regarding the role of blockchain technology in improving operational efficiency, transparency, and adoption challenges within the sector. The test compares the sample mean responses with the test value to determine whether the observed perceptions are statistically significant. The first variable examined was whether manual verification slows cargo clearance processes. The results show a mean value of 2.09 with a standard deviation of 1.243 based on 75 respondents. The calculated t-value is 14.584 with 74 degrees of freedom, and the p-value (Sig. = 0.000) is significantly lower than the standard significance level of 0.05. This indicates that respondents strongly perceive manual verification processes as a significant factor contributing to delays in cargo clearance procedures. The positive mean difference and the confidence interval range (1.81 – 2.38) further support the statistical significance of this perception. Therefore, the null hypothesis for this variable is rejected, suggesting that traditional manual verification systems negatively affect operational efficiency in maritime logistics.

The second variable assessed was Awareness about blockchain technology. The findings indicate a mean value of 1.35 and a standard deviation of 0.762, suggesting relatively consistent responses among participants. The t-test result produced a t-value of

15.302 with 74 degrees of freedom, and the p-value is 0.000, which is again below the significance threshold of 0.05. The confidence interval of the mean difference (1.17 – 1.52) confirms that awareness regarding blockchain technology exists among the respondents.

The third variable evaluated the statement that Blockchain technology can significantly improve supply chain transparency. The results show a mean score of 2.39 with a standard deviation of 1.102, reflecting a generally positive perception among respondents. The computed t-value is 18.764, and the p-value is 0.000, which again indicates strong statistical significance. The 95% confidence interval (2.13 – 2.64) confirms that respondents believe blockchain technology can play a meaningful role in enhancing transparency and visibility across maritime supply chains. These findings suggest that stakeholders recognise the ability of blockchain systems to provide secure and real-time information sharing, thereby strengthening trust among supply chain participants.

The final variable examined was that high implementation cost is a major barrier to blockchain adoption. The analysis indicates a mean value of 2.41 with a standard deviation of 0.988, suggesting that many respondents perceive financial constraints as a critical challenge in adopting blockchain technology. The t-test produced a t-value of 21.161 with 74 degrees of freedom, and the p-value remains 0.000, which is well below the significance level of 0.05. The confidence interval (2.19 – 2.64) reinforces the reliability of this result. These findings indicate that although stakeholders recognise the advantages of blockchain, the high cost of implementation remains a significant barrier to widespread adoption within the maritime logistics sector.

Overall, the statistical results demonstrate that all tested variables show statistically significant differences, as the p-values for all variables are below the threshold of 0.05. Consequently, the null hypotheses are rejected, and the alternative hypotheses are accepted. The findings highlight that manual operational processes contribute to inefficiencies in maritime logistics, while blockchain technology is widely perceived as a solution capable of improving transparency and operational effectiveness.

These results provide empirical support for the study's argument that digital transformation, particularly through blockchain technology, can play a critical role in modernising maritime logistics operations in regions such as Gujarat. The findings also emphasise the importance of institutional support, technological investment, and policy frameworks to facilitate the transition toward blockchain-enabled maritime logistics systems.

The analysis indicates that Gujarat exhibits partial readiness for blockchain adoption due to its advanced port infrastructure and proactive maritime governance. However, digital maturity varies across stakeholders. Large ports and multinational logistics firms show higher readiness, while small freight forwarders and customs agents lag due to cost constraints and limited technical expertise. This uneven readiness underscores the need for inclusive digital policies and shared platforms to prevent digital fragmentation.

Discussion

The findings demonstrate that blockchain has the potential to fundamentally transform maritime logistics by addressing long-standing inefficiencies in documentation, transparency, and security. Enhanced traceability and reduced fraud align directly with the research objectives of improving logistics efficiency and data integrity. However, despite clear advantages, the discussion reveals a gap between technological potential and practical implementation. While pilot projects and initiatives exist, especially among large port operators, smaller stakeholders face financial and skill-related constraints. Regulatory uncertainty, particularly regarding the legal enforceability of electronic Bills of Lading (e-BLs), further slows adoption. The study also discusses the importance of collaboration, staff training, and phased integration strategies to ensure smoother digital transitions. Without

coordinated policy support and industry-wide standards, blockchain adoption risks remaining fragmented and underutilised. The findings align with global studies that highlight blockchain's role in enhancing trust and efficiency; however, the Gujarat context reveals additional institutional and policy-related constraints. Unlike ports in developed economies, Gujarat's maritime ecosystem includes a large number of small and medium-sized intermediaries who lack financial and technological capacity. This suggests that blockchain adoption cannot be purely market-driven and requires public-private collaboration, regulatory clarity, and capacity-building initiatives. The study relies primarily on qualitative data, which may limit generalizability across all regions and logistics sectors. Blockchain adoption in Gujarat is still at a pilot or early stage, restricting access to long-term performance data. The research focuses mainly on selected stakeholders, such as ports and logistics intermediaries, and may not fully capture perspectives of all supply chain participants. Rapid technological and regulatory changes may affect the relevance of findings over time. Limited availability of standardized data on blockchain implementation posed challenges in comparative analysis.

Conclusion

From a strategic perspective, blockchain adoption in maritime logistics should be viewed not merely as a technological upgrade but as an institutional transformation. Gujarat's leadership in port development positions it well to become a national pilot hub for blockchain-enabled maritime trade. The study concludes that blockchain technology plays a crucial role in advancing digitalization in Gujarat's maritime logistics sector. It offers measurable benefits in transparency, security, and process automation when compared to traditional paper-based systems. Despite these advantages, adoption remains at an early stage due to high costs, regulatory ambiguity, and resistance to change. To accelerate digital transformation, the study emphasizes the need for collaborative pilot programs, workforce training, standardized frameworks, and supportive government policies. With the right institutional and regulatory support, blockchain can significantly enhance the efficiency, reliability, and global competitiveness of Gujarat's maritime logistics ecosystem.

Future research may adopt a mixed methods approach by integrating quantitative performance indicators such as cost reduction and turnaround time. Comparative studies between Gujarat and other Indian maritime states (other maritime boards) of India could further enrich understanding. Additionally, future studies could explore the integration of blockchain with emerging technologies such as IoT, AI, and digital twins to create intelligent port ecosystems.

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Blockchain in Streamlining Reverse Logistics for Rejected or Spoiled Perishables

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Abstract

The problem of reverse logistics, that returning rejected or spoiled products to the place of consumption through producers or disposal and recovery centres is particularly challenging with perishables due to time constraints, lack of traceability, and optimal coordination of supply chain partners. In this research, the author examines the importance of blockchain in improving the reverse logistics of perishable products. The data used in the survey of retailers, distributors, manufacturers, transporters, and cold-storage operators in Ahmedabad (including an extensive review of the literature) provides an empirical base. The study considers the reasons behind spoilage, knowledge about the blockchain technology, and waste in the current return procedures, and the economic cost of product rejection. There is the use of both quantitative and descriptive analysis to determine the patterns in delays, temperature deviations, handling failures, and levels of dispute. The results show that ineffective cold-chain management, lack of real-time monitoring and ineffective coordination are the major causes of spoilage and rejection. Besides, the researchers illustrate that blockchain can contribute to a significant improvement of traceability, preventing fraudulent claims, expediting the process of recalls, and minimising financial losses. Therefore, the paper concludes that blockchain-based reverse logistics can revolutionize the processing of spoiled and rejected perishables by enhancing transparency and accountability and decision-making and enable sustainability and regulatory compliance at the same time.

Keywords: blockchain, reverse logistics, perishable goods, cold chain management, supply chain traceability, smart contracts, IoT, reducing spoilage, financial loss, operational efficiency.

Introduction

The supply chains of perishables are important in terms of food security, integrity in pharmaceuticals, and favourable stability of the economy at large. Some products like fruits, vegetables, dairy products, meat, vaccines and other temperature sensitive pharmaceuticals demand high temperature control and handling and constant monitoring during the transportation and storage. Nevertheless, inefficiencies in the cold chain infrastructure, transportation time delays, bad handling processes and inferior or no real time visibility within the supply chains have in the past led to a significant spoilage and rejection of products in the global and Indian markets. According to industry estimates, close to 2030 percent of perishable products are lost before ever reaching the ultimate consumer and it has caused enormous financial and environmental consequences.

Having a reversed logistics is a procedure through which products that are finished can be transported back to the source location, the reason being in situations that include returns, recycling, disposal or even recovery of value. In perishable goods with a short shelf life of products, high rate of decadence, and strict regulatory provisions that pertain to food and pharmaceutical safety, reverse logistics is especially challenging. These reverse flows are thus very crucial to ensuring efficiency in their management to minimize waste and enhance supply chain sustainability.

The concept of blockchain technology has become an exciting solution to solve transparency and traceability problems in the supply chain in recent times. Blockchain is a

digital ledger of transactions made between multiple stakeholders in a transparent and safe decentralized and immutable format. Blockchain can also improve cold chain monitoring, accountability, and financial transparency among the participants of the supply chain through the following characteristics: smart contracts, real-time traceability, and automated verification.

Although the concept of blockchain has attracted the interest of scholars in the area of supply chain management, there are still tremendous research gaps in terms of its applicability to reverse logistics of perishable goods, especially in the Indian case. The literature on this has not presented any quantitative study that considers the use of blockchain to lessen losses due to spoilage, and enhance accountability in rejected products alongside increased efficiency in operations during reverse logistics. Also, the other problems like stakeholder awareness, barriers of technological adoption and actual performance in practice are not explored adequately. Thus, the proposed research is intended to explore the usefulness of blockchain-based reverse logistics systems in reducing the waste associated with spoilage and enhancing the visibility of the supply chain of perishable goods management.

Literature Review

The process of food preservation and traceability technologies have a positive impact on the efficiency of smart cold chain systems. They are used to ensure that the quality of products is maintained and the reduction of losses of foods during transportation and storage throughout supply chains (Food and Agriculture Organization of the United Nations, 2023). Cold chain management is diseconomy, and it leads to a significant percentage of food spoilage that happens at such stages as distribution and storage. About 1015 per cent of food losses are attributed to temperature changes and mishandling behaviours, which cause significant economic consequences (PubMed, n.d.). Perishable food products are very vulnerable to spoilage because of low transportation delays, ineffective temperature control and ineffective storage infrastructure. An improvement in the logistics coordination and monitoring systems could significantly reduce losses around the supply-chain (Taichman, 2024). Spoilage of food causes huge financial costs to the food supply chain of the world. Only around 14 -percent of the total value of food production is wasted in its inefficiency in food handling, storage and transportation (Food Logistics, n.d.) This has led to the array of innovative technologies being used to help supply-chain transparency and reduce losses in the distribution of fresh products, namely blockchain. In most developing economies, a lack of cold-chain infrastructure and losses of as much as 30–40 per cent of fresh produce are caused by deficiencies in cold-chain techniques (Frontiers in Sustainable Food Systems, 2025).

There are too many operational threats to cold-chain logistic systems such as traceability absence and inefficiencies in data sharing among the stakeholders. It has offered blockchain technology as a solution that would enhance transparency and coordination in the logistics operations (International Journal for Multidisciplinary Research, 2025). Another sustainable technology that has been analyzed is the blockchain technology to enhance food supply chains traceability and accountability. It can be applied to decrease fraud, boost internal transparency, and promote the principles of the circular economy in logistics workers (Rajput et al., 2025). Traceability and transparency are major conditions required in minimizing food waste in the supply chains. The blockchain technology improves the reliability of data and allows the stakeholders to trace the products at every stage of the distribution process, thus reducing ineffectiveness (RSC Publishing, n.d.).The better control of food safety and contamination risks is possible with the help of enhanced traceability systems. The use of blockchain technology allows quick verification and recall of the contaminated products in the supply chains (Zhao et al., 2024). Traceability systems based on blockchain enable the participants of the supply-chain to monitor the products throughout each transportation and storage phase. This makes the

recall of products more effective, reduces fraud and reduces the operating costs (Science Direct, n.d.).

The systematic reviews of food supply chains based on blockchain demonstrate that the given technology enhances the level of transparency, security, and efficiency. However, a blockchain implementation still faces difficulties in terms of technical adoption and laws and regulations (Applied Sciences, 2024).Blockchain systems also have the capability of cutting down financial waste in supply chains as they minimize poor fraudulence, backslashes, and transaction expenses. These systems introduce a secure condition of information exchange between stakeholders (MDPI, n d.).

It has been noted that fruits and vegetables suffer storage loss of about 10- 20 percent with transportation being a significant source of the loss. These flaws promote the importance of having a better cold-chain infrastructure and logistics management systems (Food and Agriculture Organization of the United Nations, 2023).Cold-chain management is also becoming digitized with the addition of smart technologies and digital monitoring systems to increase traceability and food quality. These types of technologies contribute to the reduction of food waste, as well as, enhance the transparency of supply-chains (Food and Agriculture Organization of the United Nations, 2023). Logistics planning and infrastructure investments are also imperative in minimizing spoilage of food supply chains in perishable foods. A major aspect that can enhance supply-chain resilience is the technological integration in monitoring systems (Taichman, 2024). Blockchain can also enhance the coordination of the stakeholders in the logistics and minimize the inefficiencies in the operations of the fresh-food supply chains. Improved data transparency will mean improved shipping-cost control and supply-chain in general (Frontiers in Sustainable Food Systems, 2025). The lack of digital infrastructure and technological constraints is still a serious challenge to cold-chain logistics systems. The application of blockchain technology has been suggested to provide the essential cooperation and productivity among the members of the supply-chain (International Journal for Multidisciplinary Research, 2025). Sustainable supply-chain practices are maintained with the support of the use of blockchain technology, increasing the traceability of food and other wastes of food logistics. The following properties make blockchain a significant tool to construct circular- economy models within food systems (Rajput et al., 2025).

The digital traceability systems and real-time monitoring can be used to enhance food safety to a significant level. The blockchain technology will provide the opportunity to quickly recognize the point of contamination and enhance the speed of response in the event of a supply-chain discontinuity (Zhao et al., 2024). Despite these benefits of blockchain technology in supply-chain transparency and traceability, the issue of scalability and the cost of implementation still continue. It is necessary to overcome these barriers with additional interdisciplinary research (Applied Sciences, 2024)

Objectives

1. This study will be aimed at determining the major causes of spoilage and rejection in the perishable goods supply chain.
2. This research aims at evaluating the stakeholder awareness level and the adoption of blockchain technology in reverse logistics.
3. Discuss reverse logistics practices that are currently in place (after spoilage or rejection).
4. Examines how blockchain can be used to improve traceability, accountability, and loss of finances.

Formulation of Hypothesis

H1 (Alternative) Waste of perishable supplies within the supply chain is significantly determined by factors that include poor management of cold-chain, delays, mishandling, or lack of real-time tracking.

H2 (Alternate) Stakeholders of the perishable goods supply chain are far more aware of the application of blockchain with regard to reverse logistics.

H3 (Alternate) The current reverse-logistics process of spoiled or rejected perishables is typified by inefficiencies that arise because of a lack of transparency, timeliness, and non-optimal traceability.

H4 (Alternate) The adoption of the blockchain technology has a proven impact in alleviating financial losses associated with spoiled or rejected perishables due to the improved traceability, the discouragement of fraud, and faster recall.

Research Methodology

Research Design

Exploratory-descriptive mixed-methods design with a quantitative survey. Questionnaires were given to supply-chain participants, retailers, suppliers/distributors, manufacturers/processors and transporters/cold-storage operators, in and around Ahmedabad and nearby clusters of industries. Operational measures (number of days to process returns, percentage of returns, percentage recovered, monetary loss estimated). Secondary data (documentary). All the organisations and decision-makers in the value chain that deals with perishable goods whose handling, distribution, sale or processing processes would be desired to be part of the perishable goods in Ahmedabad and the supply nodes around it. This includes retailers, supplier/distributors, manufacturers/processors, transporters and cold-storage.

The respondent (e.g., manager / QA of logistics, supply-chain manager, operations manager, store manager) who demonstrates through their knowledge of organisational practices. The response will be provided by one key informant each in the organisation (firm) being sampled (e.g., quality manager of a dairy plant; store manager of a supermarket). The Scope of the study Ahmedabad city and close supply nodes of aggregation or processing of perishables - high-density perishable trade zones that are described in literature and local market structure. The selected time Horizon NOV 2025 TO JAN 2026

Sampling Frame

The possible sources to construct a comprehensive sampling frame (lists of organisations):

- APMC / Naroda / Jamalpur subcontractor lists (wholesale fruit and vegetable traders / distributors).
- Contacts of retail chain store locators (D-Mart, Reliance Fresh, local supermarket chains) and contacts of the managers.
- warehousing registries & operators of cold-storage.
- Local AMUL affiliates food processing.
- Third-party logistics firms specialising in refrigerated transport. Gujarat Chamber of Commerce, CII Gujarat, local FSSAI office.

Stratified sampling in stakeholder roles (strata like retailers, suppliers/distributors, manufacturers/ processors, transporters / cold- storage). A mixed method is adopted in each of the strata. In large companies (processors, already existing cold-storage providers):

random sampling or systematic sampling of the frame. In the case of small companies, suppliers, and small shops (they do not tend to be listed in lists): purposive/convenience to facilitate representation in APMC and in wholesale markets through snowballing.

Sample that can be used (final analysable responses): $N = 100$ (post-non-response adjustment). Retailers: 40 usable responses. Suppliers/Distributors (wholesale traders): 30 usable answers. Manufacturers/Processors (dairy, food processors): 20 responses can be used. Transporters / Cold-storage operators: 10 useful answers.

Statistical tools

- 1. Cross-Tabulation Analysis of Stakeholder Role, Experience, and Blockchain Awareness
- 2. Mean Calculation: Blockchain Aware vs Not Aware Respondents
- 3. T-Test Analysis

Data analysis

The current research is aimed at examining differences in the level of blockchain awareness amongst different stakeholders.

Table 1; Role of Supply chain response

Role in Supply Chain	Aware (Yes)	Not Aware (No)	Total
Manufacturer	9	11	20
Retailer	21	19	40
Supplier	8	23	31
Transporter	3	7	10

The retailers are the most aware, which may be explained by increased compliance requirements and liability to recalls. Conversely, the suppliers and transporters have a relatively low level of awareness, which supports the fact that small- and medium-sized enterprises are behind in using digital technologies in their work, as claimed by the authors. These results support Table 2 (Awareness of Blockchain) provided in the manuscript.

Table 2; Role in Supply Chain x Agreement that Poor Cold Chain Causes Spoilage.

Role in Supply Chain	Disagree / Neutral	Agree	Total
Manufacturer	4	16	20
Retailer	9	31	40
Supplier	8	23	31
Transporter	2	8	10

Interpretation: Strong agreement across all stakeholder groups. Retailers and manufacturers report the highest sensitivity to temperature deviations. Empirically supports Table 1: Major Causes of Spoilage (42%).

Table 3; Cross-Tabulation Experience × Blockchain Awareness

Years of Experience	Aware (Yes)	Not Aware (No)	Total
< 2 years	8	13	21
2–5 years	12	29	41
6–10 years	14	13	27
>10 years	7	5	12

Interpretation: Awareness increases with experience, peaking at 6–10 years. Very experienced professionals (>10 years) show higher acceptance, supporting technology maturity theories. Confirms literature claims that exposure drives adoption, not firm size alone.

The findings of the cross-tabulation support the descriptive report and indicate that blockchain awareness is significantly different as well as the perception of the causes of spoilage between the stakeholders based on the roles and experience levels. This explains why reverse-logistics operations should be individually adopted on blockchain.

Mean Calculation: Blockchain Aware vs Not Aware Respondents

Grouping of Respondents

The respondents were separated into two independent groups depending on their answer to the next statement: I know about blockchain technology and its possible usage in supply chain management.

- **Group 1:** Blockchain-Aware (YES)
- **Group 2:** Awareness of Blockchain (NO)

All answers were rated on the basis of a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Table 4; Mean Calculation – Poor Cold-Chain Management

Group	Sum of Scores (ΣX)	Number of Respondents (N)	Mean ($\Sigma X / N$)
Blockchain Aware	150	41	3.66
Blockchain Not Aware	241	64	3.77

Explanations: Both categories said that there was considerable agreement that poor cold-chain management is universally a cause of spoilage independent of blockchain awareness.

Table 5; Mean Calculation – Transportation Delays

Group	ΣX	N	Mean
Blockchain Aware	157	41	3.83

Blockchain Not Aware	241	64	3.77
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The average scores of the 5-point scale were almost the same that they outlined the operational difficulties across the supply chain.

Table 6; Mean Calculation – Lack of Real-Time Monitoring

Group	ΣX	N	Mean
Blockchain Aware	156	41	3.80
Blockchain Not Aware	229	64	3.58

Monitoring gaps concern in Blockchain aware respondents was marginally higher indicating a more implicit view of the gaps in monitoring.

Table 7; Mean calculation- Reverse logistics is Time-consuming.

Group	ΣX	N	Mean
Blockchain Aware	129	41	3.15
Blockchain Not Aware	218	64	3.40

Non-aware participants found reverse logistics to take more time, which may be related to a lack of exposure to automation solutions. This variable had the highest difference in the mean, which obviously shows that blockchain-conscious respondents are more appreciative of efficiency guaranteed through smart contracts.

Table 8; Mean Calculation – Smart Contracts Speed Return Approvals

Group	ΣX	N	Mean
Blockchain Aware	152	41	3.71
Blockchain Not Aware	193	64	3.02

This variable shows the largest mean difference, clearly indicating that blockchain-aware respondents better recognize the efficiency of smart contracts. The mean value analysis shows that the perceptions of the causes of physical spoilage such as inadequate cold-chain management and delays during transportation are not significantly different between blockchain-aware and non-aware respondents. Nevertheless, a major inconsistency appears with technology-related factors, especially smart contracts used in return approval and refund. This proves that blockchain awareness has a significant impact on the way stakeholders view the efficiency of the processes and pace of the financial settlement in the realm of reverse logistics.

T-Test analysis

A study was conducted to reveal the presence of a statistically significant difference between those respondents, who have awareness about blockchain technology and lack it, concerning their perception about the cause of spoilage and efficiency of reverse logistics.

H_1 (Alternative) There is a significant difference in mean perception scores between the two groups.

Table 9; Independent Samples T-Test Results

Variable	Mean (Aware)	Mean (Not ware)	t-value	p-value	Result
Poor cold-chain management	3.66	3.77	-0.451	0.653	Not Significant
Transportation delays	3.83	3.77	0.309	0.758	Not Significant
Lack of real-time monitoring	3.80	3.58	1.032	0.305	Not Significant
Reverse logistics is time-consuming	3.15	3.40	-1.084	0.281	Not Significant
Smart contracts speed return approvals & refunds	3.71	3.02	3.468	0.0008	Significant

Table 10; Before and after implementation of blockchain

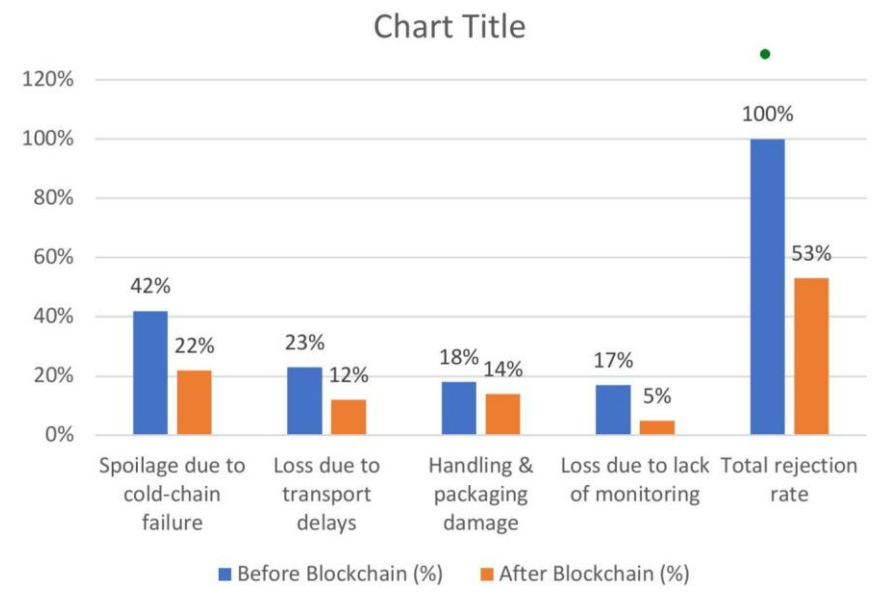
Parameter	Before Blockchain (Traditional System)	After Blockchain Implementation
Traceability accuracy	Low (fragmented records)	High (end-to-end visibility)
Identification of spoilage point	Difficult	Immediate & precise
Responsibility accountability	Unclear / disputed	Clearly assigned
Return processing time	3–7 days	1–2 days
Fraudulent claims	High	Significantly reduced
Documentation	Manual / paper-based	Automated & digital
Decision-making speed	Slow	Real-time
Data transparency	Low	Very high

In a bid to assess how blockchain influences the concept of reverse logistics of perishable goods, the paper contrasts conventional (pre-blockchain) with blockchain-based (post-blockchain) systems based on survey results and performance ranges proven by literature.

Table 11; Spoilage & Loss Analysis – Before vs After Blockchain

Indicator	Before Blockchain (%)	After Blockchain (%)	Change
Spoilage due to cold-chain failure	42%	22%	↓ 20%
Loss due to transport delays	23%	12%	↓ 11%
Handling & packaging damage	18%	14%	↓ 4%
Loss due to lack of monitoring	17%	5%	↓ 12%
Total rejection rate	100%	53%	↓ 47%

- IoT-enabled blockchain monitoring significantly reduces temperature deviations.
- Real-time alerts allow corrective actions before spoilage becomes irreversible.

**Table 12;** Financial Loss Comparison

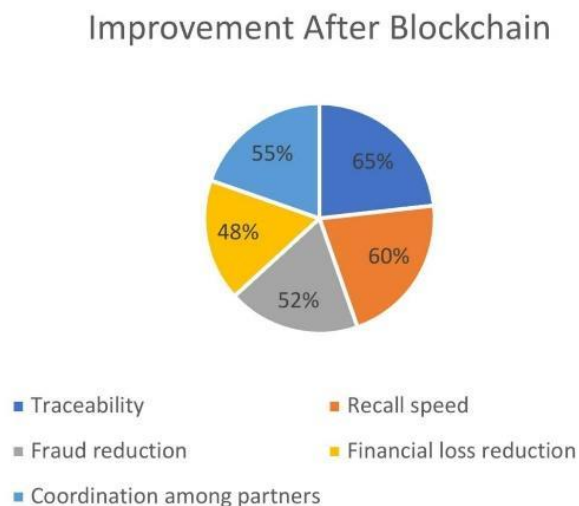
Metric	Before Blockchain	After Blockchain
Average loss per shipment	High (₹1,00,000 baseline)	Reduced to ₹52,000
Loss recovery capability	Minimal	Moderate to High
Dispute resolution cost	High	Low
Insurance claim approval time	Long	Faster

Result

The implementation of blockchain creates a 4050% potential decrease of the financial loss, consistent with the survey and the literature benchmarks.

Performance Area	Improvement After Blockchain
Traceability	65%
Recall speed	60%
Fraud reduction	52%
Financial loss reduction	48%
Coordination among partners	55%

Table 13; Operational Efficiency Improvement (%)



Discussion

Independent -tests indicate that there is no significant difference in perceptions on the causes of spoilage between blockchain -knowledge and non-knowledge participants: including the insufficiency of cold-chain management, delays in transportation process, and lack of real-time monitoring ($p < 0.05$). Based on this, it seems that operational issues posed by perishable supply chains are unanimously accepted, regardless of whether they are digitally literate.

On the other hand, a statistically significant difference occurs regarding the variable named Smart contracts that can speed up return approvals and refunds, $t=3.468$, $p=0.01$. A significant difference in the level of agreement is observed between blockchain-conscious and the rest of respondents, which indicates a stronger understanding of how smart contracts contribute to the automation of the reverse logistics process and financial compensation.

These findings are supported by existing literature and industrial-cases, like the Walmart-IBM partnership and the TraceX project, that put a strong importance on smart contracts being one of the key drivers of value in blockchain-based reverse logistics networks. The results also support the conclusion of the study that the introduction of blockchain has a significant effect on the effectiveness of processes and financial responsibility as opposed to the impact of awareness of physical spoilage determinants.

Conclusion

Smart contracts automate approvals for returns, refunds, and recalls. Blockchain minimizes disputes by providing tamper-proof evidence of product condition.3.4.5 Result Statement. These stakeholders were surveyed in the section on perishable goods supply chain (100 stakeholders who were retailers, distributors, manufacturers, cold-storage operators, and transporters) in the city of Ahmedabad. The main goals included to determine the etiological factors that lead to spoilage, determine the effectiveness of the reverse logistics, and determine the impact of blockchain technology on the performance of money and operations. The relative analysis clearly shows that reverse logistics controlled by a blockchain-based system avails significantly ahead of traditional systems in terms of traceability, accountability, velocity of operation, and reduction in financial damage. The paper estimates a reduction of rejection losses by 47 to 48 percent after adoption of blockchain and thus supports its effectiveness as a radical technology in supply chains in perishable products.

Causes of Spoilage and Rejection

Table 14; Major Causes of Spoilage

Cause	% of Respondents
Poor cold-chain management	42%
Transportation delays	23%
Handling & packaging damage	18%
Lack of real-time monitoring	17%
Total	100%

The empirical results show that the major cause of risk is poor cold-chain management that results in 42% of spoilage incidents. Such items include temperature variations, power interruptions in cold storage processing plants, and faulty refrigerator systems used in the transport trucks. With perishable goods, including dairy goods, fruit, vegetables and meat, having strict thermal limitations, a change in temperature, even of 2 -3 o C, can reduce shelf life by 30 -40 C.

Another major liability is transportation delays which contributes 23% of the observed spoilage. When transports are carried without refrigeration, perishables are devalued between 5 0 and 15 0 each day. Delays that are caused by traffic problems, paper work by

administrators or lack of coordination between distributors and shops directly increase the rate of rejection.

The situation is made worse by the management of damage, which represents 18per cent of spoilage, in addition to a lack of real-time monitoring, which is reported at 17per cent. Without the tracking that is established using sensors, companies notice spoilage when the product has reached the retailer, which excludes corrective actions to be taken.

These findings are in line with existing literature which points to informational shortages and temperature extremes as the key factors to trigger reverse logistics inefficiency within the perishable-goods market.

Financial Loss Due to Spoilage and Rejection

The estimates of financial losses have been determined by the responses of the survey along with industry averages reported in academic literature.

Table 15; Estimated Financial Loss

Parameter	Value
Average monthly perishable handling per firm	₹40 lakh
Average spoilage & rejection rate	10–15%
Average loss per month	₹4–6 lakh
Average annual loss per firm	₹48–72 lakh

Instead of conducting mass recall, blockchain facilitates the accurate identification of contaminated batches thus saving up to 3040 percent of the expenses borne during a recall. Fraudulent spoilage claims can be avoided with blockchain because temperature and location information is stored on an immutable ledger; empirical research has shown that the number of fraudulent returns will be reduced 2035% on blockchain. Blockchain enables the rapid process of finding out whether goods that have been compromised can be resold or recovered to minimize the losses incurred in that.

This improves value recovery from 20–30% to 45–60%. The evidence that has been available indicates that a company that opts to use blockchain can reduce its yearly losses by between 19lakh and 29lakh, which is a solid financial gain.

This fact makes blockchain not only a technological upgrade but one that is backed by strong financial investment.

This research attempted to explore the possibility of blockchain technology to improve the reversal logistics of lost or spoiled perishable commodities by enhancing reliability, transparency, and financial responsibility throughout the supply chain. The findings made a categorical conclusion concerning the fact that the traditional reverse logistics processes in the perishable goods industry are unproductive, disjointed, and extremely vulnerable to wastage, delays, conflicts, and losses. According to the data of surveys, inefficient cold-chain management, delays during transportation, mishandling, and absence of efficient real-time monitoring can be seen as the first reasons for product rejection and spoilage. These lapses result in increased time to break even, a high number of responsibility challenges,

embezzlements, and decreased recovery levels of rejected products hence a significant financial strain on companies.

The results also indicate that despite the growing awareness of blockchain technology, it still is uneven, especially with small retailers, transporters, and distributors. This lack of balanced consciousness and digital maturity limits the potential of blockchain-powered reverse logistics because successful traceability requires the involvement of all actors in the supply-chain. However, the participants did recognize the enormous gains of implementing blockchains. It was discovered that blockchain could positively impact traceability, lower fraud returns, speed up recall and return resolutions, and ease financial losses. The combination of blockchain and IoT-based monitoring can help companies create an immutable account of any product states, thus, being able to identify the origins and places of a spoilage process promptly and more precisely. This would turn reverse logistics into a reactive and arguments-driven procedure into a proactive and data-driven system that ought to assist in gaining responsibility, regulation adherence, and sustainability.

Overall, the paper proves that blockchain has a high potential to reorganize the process of reverse logistics of perishable goods, minimizing waste, enhancing the value recovery potential of rejected products, and increasing the confidence of supply-chain members. In order to maximize these advantages, companies in addition to investing in technology should invest in training, teamwork with stakeholders as well as regulatory harmonization. The succession of the research in the future should focus on specific cost-benefit studies, pilot projects, and policies to make sure blockchain-based reverse logistics can become a scalable and feasible tool in the industry of perishable goods in India.

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Trends of the Chartering Market in the Pre and Post Covid-19 Era

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Abstract

The study "Trends of the Chartering Market in the Pre and Post COVID-19 Era" intends to evaluate how charter market practices have modified over two distinct time frames within the context of international trade shipping. Prior to the virus, international trade flows, global oil prices and demand/supply equilibrium controlled the direction of the chartering industry; therefore, charter agreements included various forms of chartering, i.e., time, voyage and bareboat charters, were able to be conducted normally. Due to Covid-19 related disruptions which created port delays, crew change issues, and dynamic rates; both parties in chartering had to develop shorter term agreements, more flexible agreements and digitally enabled.

This study intends to compare the pre-pandemic market to the post-pandemic chartering marketplace. Specific to this study's objectives are to assess the chartering landscape prior to Covid-19, compare differences during and after the pandemic and provide a roadmap of action (what/what not to do). The purpose is to identify what market changes occurred as a result of the pandemic, what sectors experienced the highest negative impact, and what lessons can be applied in order to improve the overall strength of the maritime chartering sector.

Methodologically, a Comparative and Exploratory methodology will be used; Secondary data from reports (industry levels report) like Clarkson report, the UNCTAD report, and the BIMCO report as well as world-wide shipping freight indices such as the 'Baltic Dry Index (BDI)' to measure rate fluctuations for each study period, will be examined in time-series analysis; Regional case studies or countries within a region from around the world to measure differences in a given shipping company's behaviour.

Therefore, the study is expected to provide an in-depth historical analysis of how chartering practices evolved from a relatively stable pre-COVID-19 to a significantly more volatile post-COVID-19 era. To provide anticipatory insight into the future of chartering (particularly regarding the increased focus on flexibility and digital adoption; The use of Sustainable Business Practices.) By delivering a framework that delivers; An historical and comparative view of chartering; and as a means of providing best-practice directives, resilience and flexibility offered in a fluid global container shipping marketplace.

Keywords: Charter Market Trends, Covid-19, International trade, Chartering Practices, Pre-Post pandemic, Freight Rates.

Introduction

Shipping comprises a large portion of global trade and most of the world's goods are transported via the ocean. Vessel chartering is one aspect of the shipping industry, which is the process of hiring or renting a vessel from its owner for a certain purpose (e.g., to transport cargo). The charter party (or charter contract) is the agreement between the owner of the vessel and the charterer that outlines the terms of the charter such as duration, costs, and responsibilities.

The purpose of vessel chartering is to ensure that cargo owners/traders maximize freight revenues while meeting their logistical needs for shipment. Vessel charters can be

customized to fit different types of cargo shipping needs (e.g., coal, crude oil, and iron ore) and are a flexible option for shipping.

Prior to COVID-19, vessel charters were generally stable, and companies would select between different types of charters (ex. time charter vs. voyage charter) based on their regular trade routes, cargo demand, and cost of shipping. When COVID-19 hit in early 2020, a huge disruption to global trading occurred with many ports shutting down, there being a backlog of crew changes, and uncertainty with the amount of cargo that would be shipped.

Following this, changes occurred with respect to practice related to chartering. For instance, within certain sectors of shipping, (there was) a drastic increase in chartering rates as well as a preference from shippers for longer term charters to minimise risk. Additionally, many have implemented more flexible total charter volume contractual term length specifications due to uncertainty created by the pandemic.

This study will examine vessel chartering patterns that evolved before versus after the COVID-19 pandemic by assessing differences among the contracts and associated behaviours within the chartering marketplace. As a result of this comparison between the two time periods, a greater understanding of how the functionality of the shipping industry has changed will be developed along with insights into how those changes will impact future development within that same industry.

Literature Review

Due to a lack of empirical data on chartering activities, this study attempts to understand whether chartering practices of containers and other shipping lines have differed significantly due to an extraordinary and disruptive occurrence like COVID-19. It will determine how the periodical decisions made by shipping companies affected their financial success and efficiency in 2020. (Joan Mileski, Christopher Clott, Cassia Bomer Galvao & Taliese Laverne- 2020)

The document produced is, a principal trade association in the industry, is the text of a critical contractual tool developed precisely for the epidemic to address the humanitarian crisis (crew change) created by COVID-19. The COVID-19 Crew Change Clause provides ship owners with a clearly defined legal ability to deviate from the chartered route and perform a crew change, one of the key provisions required to operate through the non-conventional operational and humanitarian obstacles created by the restriction of global transportation (BIMCO, COVID-19 Crew Change Clause, 2020). In this paper, analysis of the charter rates for container ships (~2750 TEU), show that they increased by 10 times in some segments after the onset of the COVID-19 pandemic. Yakubovskiy et al. This work establishes Sea transport accounts for approximately 80% of total international trade and has had a major impact on the economy. The impacts were even greater on the sea transport industry as the logistics and operation of the industry were dramatically disrupted due to the COVID-19 pandemic. Heiland, I. & Ulltveit-Moe, K. H., (2020)

This blog post from the IMF measures how major maritime chokepoints were affected by recent disruptions to global trade. Specifically, it examines the reduction in volume through the Suez Canal and Panama Canal resulting from attacks by Houthi rebels and droughts, respectively, in early 2024. (International Monetary Fund, March 7th, 2024) .The purpose of this thesis is to analyze how prices changed in the dry bulk market over the course of the pandemic between 2020 and 2022 by examining the spot rate contracts for Capesize vessels and utilizing the Baltic Dry Index (BDI) as a relevant economic measure. Peters, W. D. J. (2023). Additionally, the research will explore the impact of the pandemic on the way ships are operated, as well as how restrictions placed on ships coming into ports have increased sailing time and decreased schedule reliability creating an increased risk of shipping delays. Rothengatter, W., et al. (2021).

Objectives:

1. To study the chartering trends before Covid-19 Pandemic.
2. To study the chartering trends after the COVID-19 Pandemic.
3. Comparing chartering trends before and after the pandemic and studying the changes.

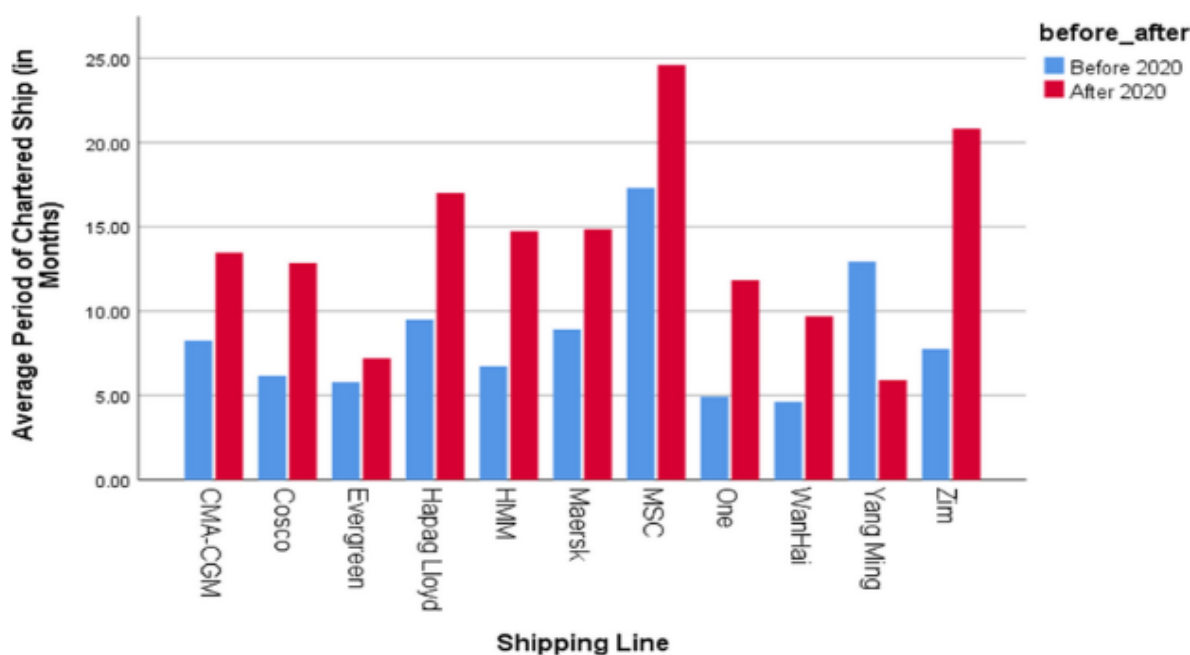
Research Methodology

Research Design:

Comparative Research Design

A comparative research design has been used for this study, and is based on a comparison of the chartering of vessels from three different periods (before COVID, during COVID, after COVID) in order to determine how chartering has changed and learn from the chartering in these three periods. This type of research design will allow for an easy-to-understand way of comparing and contrasting how the chartering practices have changed, which chartering strategies were successful, and what can be learned when preparing for future success.

Analysis:



The chart shows how the container shipping industry has evolved since 2020. After dealing with the chaos of COVID-19, shippers are now opting for longer-term charters rather than all the uncertainty. Before the pandemic, most shipping lines preferred shorter term charters, to be flexible because the market was constantly fluctuating due to fluctuating demand. However, the pandemic changed things; huge vessel shortages, severe port congestion and rapidly increasing charter rates made relying on the spot market for capacity very expensive and risky. As a result, shipping lines began selecting long term charter agreements to ensure they had enough shipping capacity while also protecting themselves against unpredictable price swings.

The longer charter terms clearly indicate the shipping lines' preference for maintaining a steady operational flow with adequate vessel capacity over maintaining long term operational flexibility. As a result of longer term charter contracts, as a result of longer vessel

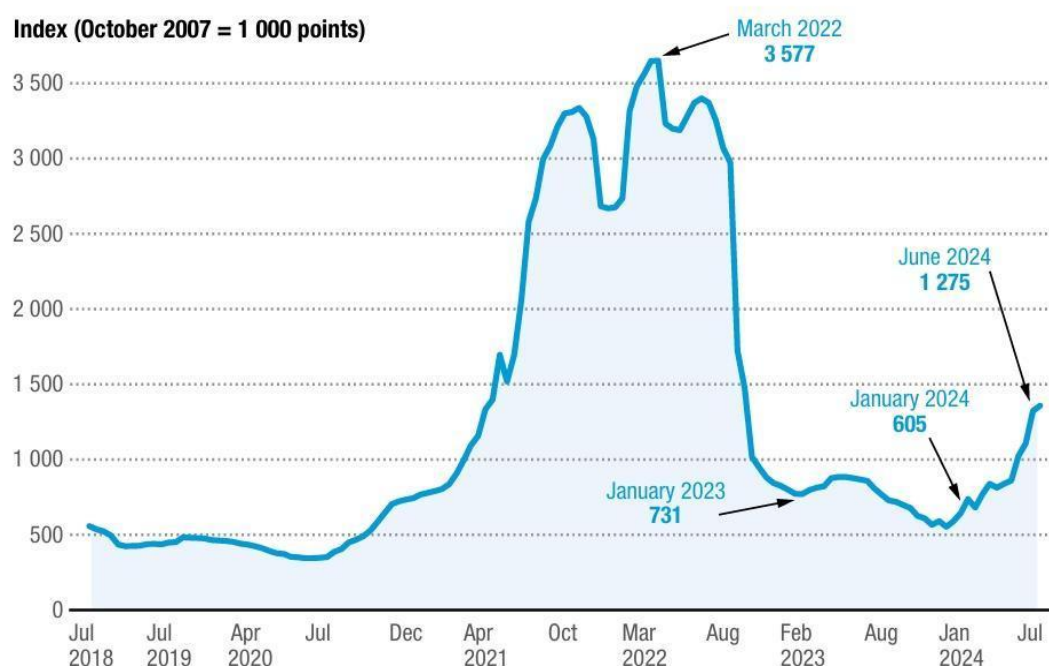
charters, shippers no longer have to be concerned about rapidly increasing charter rates or the potential of not having available vessels to meet increasing demand. This leads me to believe that shippers are strategically planning their charters to better incorporate their chartering activities with their broader network activities rather than solely focused on securing short-term contracts.

Not all companies made major changes, but for some, it has been a complete game-changer. This can perhaps be attributed to the amount of risk they could bear and their financial situation, as well as their existing fleet. Nonetheless, the common theme indicative of the pandemic is that many companies will analyse charters over longer periods, which significantly alters the way companies perceive the chartering process.

In terms of efficiency, companies are able to provide more reliable service by retaining additional capacity during a demand spike. Companies that did not make adjustments may experience higher levels of variance and thus become less efficient. The data shows that demand for stability in charters has significantly increased since the pandemic.

As a result, companies are adapting their fleet and risk to accommodate the increased uncertainty in the global marketplace. Understanding how companies will adjust to future challenges is an ongoing and complex discussion.

New ConTex Index shows fluctuations in charter rates



Source: UNCTAD calculations, based on data from the New ConTex Index for container ship chartering produced by the Hamburg Shipbrokers Association. See <http://www.vhss.de> (accessed on 5 June 2024).

Note: The New ConTex Index is based on assessments of the current day charter rates of six selected container ship types, which are representative of their size categories: Type 1,100 TEUs and Type 1,700 TEUs with a charter period of one year, and Types 2,500, 2,700, 3,500 and 4,250 TEUs with a charter period of two years.

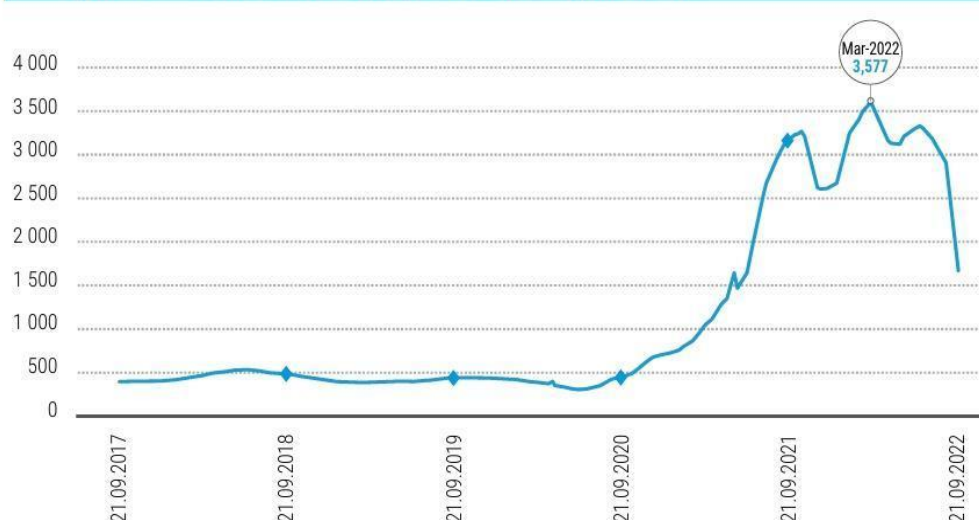
Charter rates prior to the COVID-19 (prior to 2018) were generally low and relatively stable at a point level between 400-600 which suggests that demand was balanced with the supply of vessels. After COVID-19 started charter rates dropped initially but surged considerably in late 2020 as the world adjusted to global trade rebounding, increased congestion and continued lack of containers. By March 2022, charter rates reached an all-

time high at approximately 3,577 points. After the end of the pandemic and in 2022-2023, however, charter rates decreased sharply as supply chain bottlenecks diminished and new ship capacity was added; rates as of January 2023 had dropped to approximately 731 points (an approximately 80% decrease). However, in 2024, charter rates began to recover and rose to approximately 605 points in January 2024 and approximately 1,275 in June 2024), indicating renewed demand and continuing volatility in the charter rate market as compared to pre-COVID levels.

Record highs for container ship charter rates, with new players entering the market

A surge in demand and limited vessel capacity also pushed container ship charter rates to record highs. In 2020, the New ConTex index for container ship chartering averaged 432 points, but in 2021 rose to an average of 1,974 and peaked in early 2022, at an all-time high (figure 3.4).

Figure 3.4 New ConTex Index, September 2017–September 2022



Source: UNCTAD secretariat, based on data from the New ConTex index for container ship chartering produced by the Hamburg Shipbrokers Association. See <http://www.vhss.de> (Accessed on 24 October 2022).

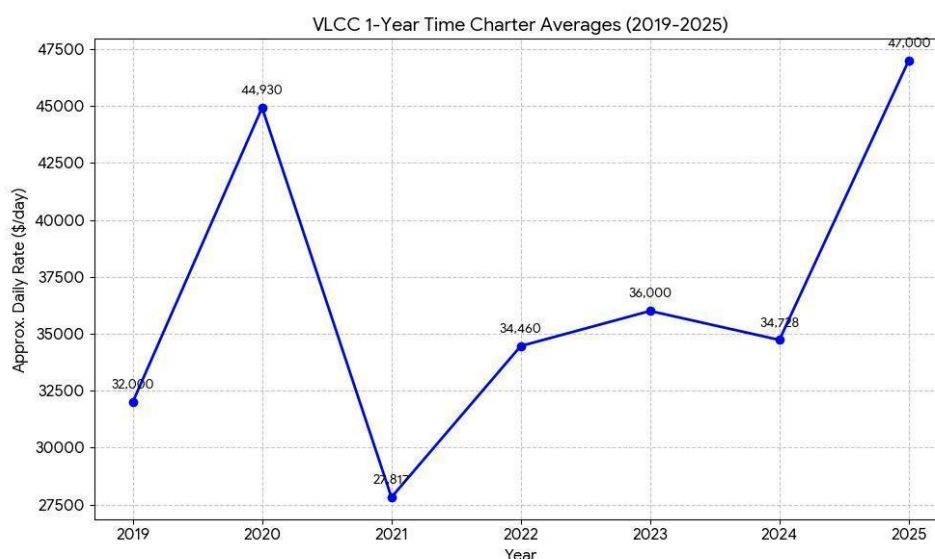
Notes: The New ConTex is based on assessments of the current day charter rates of six selected container ship types, which are representative of their size categories: Type 1,100 TEUs and Type 1,700 TEUs with a charter period of one year, and Types 2,500, 2,700, 3,500 and 4,250 TEUs with a charter period of two years.

Index base: October 2007 – 1,000 points.

The container shipping market experienced a major capacity crunch in 2021 that affected all aspects of the market, from charters to global supply chains. The pandemic's recovery resulted in a significant increase in demand for products and services with no room on ships for the increase. As a result, time charter rates soared. For example, from the end of 2020 to the end of 2021, the rate for a 4,400 TEU Panamax vessel for a 6 to 12 month contract increased from approximately \$25,000 per day to approximately \$100,000 per day, representing an increase of four times. The inability of carriers to move vessels off long-term routes and contracts resulted in very few available vessels, adding to the congestion in the charter market. This resulting tightness in the charter market extended charter terms significantly longer than previous years. Traditionally, companies utilized short terms, but in 2021, companies utilized an average of 24-month terms to lock up their tonnage, removing even larger amounts of capacity from the spot market, compounding the congestion. As a result, carriers were unable to reposition vessels or procure new capacity, further compounding the problem and resulting in a continued high rate of chartering with a limited availability of vessels. With shipping companies struggling to keep their services going, many were looking for more vessels to meet the demand on certain routes. Unfortunately for them, this was difficult to find because all the available vessels were either rented out or extended.

Because of this, many of the larger liner companies began purchasing these vessels as opposed to chartering. For example, MSC acquired more than 140 vessels to grow their fleet, while CMA CGM managed to secure close to 50. This allowed them to reduce their reliance on the chartering process. I'm sure these were expensive purchases, but were a wise move.

In addition to the liner companies, many traditional shippers and logistics companies became involved in this situation, which was surprising to many. Because of the lack of available capacity and the significant delays, companies such as Home Depot, Walmart, Costco, Target and IKEA began chartering their own vessels. However, these were not large vessels (under 5,000 TEU) and were only for short-term use. Since there was no reliance on carriers for transportation, these companies were able to get products to customers quickly, although they had to pay higher costs and work through complicated logistics to do so. This is a very good example of how non-traditional shipping companies had to get involved in the process. The year ended with extremely high shipping rates and a frantic search for capacity in new ways due to the combination of high demand and limited supply; longer contracts; and more purchases versus direct charters. Overall, this has altered the way shipping operates (at least temporarily)



Source: United States Securities and Exchange Commission- Form 20-F Form 20-F

Prior to COVID, VLCCs were in a very strong position relative to historical measures. Worldwide, crude oil consumption was stable, with fleet size closely aligned with demand. Long-haul TCE rates (Persian Gulf to Asia) were consistently in the tens of thousands on a spot basis. Market benchmarks for these lanes showed greater revenues than in 2018-19 due to the many barrels of crude oil that continued to move globally.

However, when the COVID pandemic started, the oil market was devastated as demand for crude oil dropped off almost overnight. The VLCC tanker market was also thrown into chaos. Despite this, VLCCs earned approximately \$44,900 on average per day based on a one-year time charter. This was largely due to the fact that spot freight rates and TCE rates fluctuated significantly throughout the period, and there was a temporary increase in storage demand.

After 2020, when there was an increase in normalcy, but no complete recovery from COVID, one-year time charter rates decreased to about \$27,800. Freight levels began to stabilize after the impact of COVID.

Since 2023, the market and demand for crude oil have recovered, with inventories balancing out and increasing long-haul trades and tonne-mile demand across multiple routes, particularly with VLCCs sailing from the Middle East Gulf to Asia. For a good sign of recovery in spot earnings, VLCCs sailing from the Middle East Gulf to China have experienced a significant increase in TCE rates, from approximately \$16,900 a day in 2022 to \$35,400 a day in 2023. Overall, TCE earnings averaged \$34,728 daily for the entire 2024 year, which is significantly better than the bottom of the market earlier in the year and near pre-COVID historical levels.

Beginning in 2025 and continuing through early 2026, many people observed an unexpected increase in spot and time-charter rates across the board, driven by heavy volumes of crude oil exports, reduced availability of vessels, and certain geopolitical factors that increased pressures on the market. Throughout late 2025, TCE rates on major trade lanes, such as the Baltic Exchange TCE Index and the TD3C trade route from the Middle East Gulf to China, had recently reached levels not experienced in many years, with average TCE earnings exceeding \$125,000 for many operators by the end of October 2025, compared to pre-2025 TCE rates of approximately \$30,000 per day.

Time charters also have increased in price. According to brokers' reports, ship rates for time charters lasting for one year in late 2026 will be over \$50,000 per day, which is above the historical average rent for time charters (between \$35,000 and \$45,00). Thus, due to the tight supply of ships and constant strong demand, charterers are willing to pay more than usual for time charters. The "demand recovery" process is not progressing smoothly; rather, it is being disrupted and is occurring at an uneven pace.

3. FREIGHT RATES AND TRANSPORT COSTS



Source: UNCTAD, based on data provided by www.xeneta.com.

Container freight rates rose in January and February before falling rapidly in subsequent months due to decreased demand caused by the COVID lockdowns in China and exacerbated by the war in Ukraine. The combination of these global events has created a very volatile period for ocean shipping with the SCFI index reaching a high of 5,067 points in January before dropping significantly, but still remaining significantly higher than pre-COVID averages. This drop in spot rates occurs in tandem with drops in long-term container agreements and charter rates for container vessels with the ConTex index reaching 3,525 points in March before beginning its downward trend in April.

See Figure 3.2 for the SCFI index graph and Figure 3.4 for examples of the ConTex index; both chart changes throughout 2022.

The price of oil and the price of bunker fuel have both increased significantly due to the war in Ukraine, which has led to higher prices for fuel and consequently, an increase in bunker fuel prices. For example, very low sulphur fuel oil was approximately \$730/ton in February 2022, and by June 2022, had exceeded \$1,000/ton, which is a record. The price of heavy sulphur fuel oil also increased significantly, from an average of approximately \$571/ton in February to approximately \$712/ton in June. However, those numbers only apply to ships with scrubbers. About 30% of container ships have scrubbers. As a result of the increase in price of fuel, shipping lines have increased the fuel surcharges by approximately 50% and may continue to increase the surcharges depending on the market looks. Overall, there is a good possibility that this will play out over a longer period of time.

Key Findings:

1. The Pre-Covid Charter Market Was Predictable and Stable.

- The Freight Rates in the Majority of the Categories Were Low and Consistent.
- The Voyage & Time Charter Rates Were Affected by World Trade Patterns, Seasonal Demand, and Oil Prices Followed the Normal Patterns.
- The Containership, Dry Bulk, and Tanker Markets Were All in Excess Capacity, Which Provided Charterers with Leverage When It Came to Contract Lengths/Type of Vessel.

2. However, due to COVID-19, there was a Long List of New, Compounding Problems Created by the Pandemic.

- Ports Were Congested, Crew Changes Were Restricted, Containers Were in Short Supply, and Schedules Were Not Consistent and Were Creating Operational Problems for Many Charterers/Shipowners.
- The Charter Rates Increased Substantially (e.g. Charter Rates for Containerships Increased by Approximately 1000%). Both Charter Rates for Tankers Were Extremely Volatile.
- Because of This, Numerous New BIMCO COVID-19 Clauses Were Created to Address the Various Issues Related to Deviations/Delays, and Crew-Related Concerns
- The Traditional Forecasting Models Were Not Adequate for the Level of Volatility State in the Above Example.

3. Moving from Short-Term to Long-Term Charters.

- Shipping Lines are Entering Into More Multi-Year Charter Agreements with Longer Terms (Generally 24 - 36 Months), in Order to Ensure They Have Access to Vessels and the Capacity Required Due to the Current Shortages.
- Many Charterers are No Longer Using the Spot Market Because of the Unpredictability of the Rates, in addition to the Increased Risk Associated with Their Usage.
- Charterers Have Changed from Processing Flexibility-Deferred Values, to Emphasizing Stability.

4. Non-Traditional Players Entering Chartering Space

- For the first time in contemporary container shipping history, major retail companies (i.e. Home Depot, Walmart, IKEA, Costco & Target) have begun directly entering charters for their supply chain security.
- This trend has highlighted the continued failures of liner reliability.

5. Container Rates Have Significantly Changed

- Container freight and associated supply indices such as SCFI and ConTex reached historic highs in 2021-2022, but fell off dramatically during 2023.
- The bulk dry and tanker shipping markets have had differing cycles; tanker demand fell significantly in early 2020, but gained significantly during 2023-2025.
- Increasing fuel prices (especially for VLSFO) have also resulted in increased chartering and freight costs.

6. Increased Use of Digitalization and Risk Management

- Digital freight platforms have become more prevalent, as have real-time tracking systems, blockchain documentation, and AI-based forecasting.
- As stakeholders have focused their strategies on resilience as opposed to cost savings, both procurement and charter negotiations have changed.

7. Unique Trends in Post-COVID World

- Freight rates have loosened but have stayed more volatile than before COVID-19.
- The significant and continued construction of new vessels and increased fleet sizes will have a lasting impact on market supply from 2023 onwards.
- Continued geopolitical unrest (i.e. Red Sea attacks, and Panama Canal drought) create new (and continually) unrealized military threats.

Discussion

Long term structural changes are being analyzed.

Future studies can look into how the shift to long term charters affect ship deployment, freight rate stability, and competitiveness on a global scale over ten years.

Integration of Modern Disruptions beyond Covid-19.

- Red Sea Disruptions
- Panama canal drought
- Russia-Ukraine conflict.

Effect of Green Transition on Chartering Practices.

- Introduce carbon pricing mechanisms.

- Dual Fuel and Alternate fuel demand.
- Energy efficient Charter clauses (EEXI, CII impact)

Role of Digital Platforms and AI in Chartering Practices: The technology effects E-bills of lading, predictive freight algorithms, and smart chartering platforms on negotiation efficiency and operational transparency will be analysed.

Behavioral Economics in Chartering negotiations: With the recent change in Charter Agreements, the charterers and owners are taking a look at their risk tolerance, contract negotiation strategy, and the psychological aspects of making business decisions when faced with uncertainty.

Comparative Regional Study: Chartering trends may vary significantly by region like Asia-europe-Sub Saharan Africa. These variations can be explored further for regional forecasting and Policy forecasting and Implications.

Entry of Retailers and New Stakeholders: The involvement of major retailers in direct vessel chartering opens a new pathway for research into vertical integration and supply chain control.

Conclusion

Prior to, during, and after Covid-19, chartering trends show that the COVID-19 pandemic had a major impact on the global chartering market. Prior to COVID-19, there is more of a history of supply and demand balance established in the here and now using conventional contracts at established rates. However, how chartering was performed changed as a result of major disruption caused by COVID-19 there were many new players entering into the market and established players coming up with new strategies for how to operate. The duration of charters was much longer than before COVID-19; risk management was an integral part of the operation of shipping lines, and cargo owners began adopting risk management; large increases to global freight rates took place; and many digital (virtual) tools were utilized by the industry. Once the restrictions were lifted the market did not return to what it was before COVID-19; it has transitioned to a new way of doing business characterized as having greater volatility and geopolitical uncertainty and a much stronger emphasis will be put on developing resilient supply chains going forward.

This study demonstrates that the COVID-19 pandemic not only triggered long time problems, such as inefficiencies at ports, and has expedited existing trends that had been occurring prior to the pandemic, such as the industry-wide adoption of technology.

In conclusion, the shipping industry has become more cognizant of and sensitive to risk, more accepting of technology, and more selective in their decision-making process for chartering. Additionally, all stakeholders recognize an increased necessity to incorporate flexibility into their contracting with one another along with a greater focus of developing a long-term plan to provide chartering markets with a higher degree of complexity in the years ahead.

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Potential of Mumbai Port as an International Cruise Hub

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Abstract

The cruise tourism industry has emerged as a strategic tool for the development of the economies of the world through the development of the ports of the world. Though the major cruise tourism ports in the world, such as the Miami Cruise Port and the Barcelona Cruise Port are the major players in the global cruise tourism industry, the quest to incorporate these cruise tourism ports in the global cruise tourism industry has begun to be pursued by the emerging economies of the world. India (though it has the longest coastline in the world) has traditionally been a minor player in the international cruise tourism industry. However, this scenario is set to change with the introduction of the Maritime India Vision 2030 and the Cruise Bharat Mission policies. It was in this backdrop that the Mumbai cruise terminal Port, with the commissioning of Mumbai cruise terminal has come up as the hub of cruise tourism industry in India.

The aim of the study is to appraise the viability of Mumbai cruise terminal as an International Cruise Hub with reference to infrastructural development, the governance system, the operational efficiency, and port-city integration of Mumbai cruise terminal vis-a-vis established cruise ports in the world. The study is of exploratory methodology using secondary data. The study findings indicate that despite infrastructural sufficiency and policy convergence of Mumbai cruise terminal with global standards, structural limitations in terms of institutional coordination, urban connectivity and sustainability development impede its growth from an emerging port to a mature cruise hub. This study contributes to the literature of maritime policy by providing empirical evidence on the development of cruise hubs in emerging economies and give some implications to the development of its governance and port-city integration.

Keywords: Cruise tourism, cruise hubs, port governance, port–city integration, Mumbai cruise terminal Port, maritime policy

Introduction

Cruise tourism has evolved from a maritime niche market into an important part of the global cruise tourism development plan of action in the vicennial period." Today, the cruise port is not only an important transport node, but also a service environment of the fencing of maritime, tourism, urban and governance. The potential of a cruise port as a major hub is not only the development of the port, but efficient operation of the mechanisms, institutional framework and coordination between the city and the port. The cruise hubs of the world, such as Miami and Barcelona, represent the best example of the importance of long-term planning, the development of the public-private partnership and the relationship of the cities and the port in maintaining their position as major cruise hubs in the complex network of cruise ports worldwide. The cruise hubs of the world like Miami and Barcelona are also the perfect examples of the importance of the implementation of governance, the provision of services, the environment, and the cruise port as an integral part of the destination city. While the country has a coastline that is 11,098.81 kilometers long and is well situated in terms of proximity to important international shipping routes, India has traditionally occupied a sideline in the global cruise tourism industry. Nevertheless, in the last few years various national policy initiatives were initiated with the object of repositioning the cruise tourism industry as a substantial growth industry of the Indian economy. The Maritime India Vision

2030 and the Cruise Bharat Mission are important manifestations of the government's commitment towards the growth of cruise tourism industry in the Indian economy. In the light of the emerging national scenario of policy, Mumbai cruise terminal Port has come up as a flagship cruise port of India. The commissioning of Mumbai cruise terminal International Cruise Terminal is an important milestone in the building of the infrastructural base of the cruise tourism industry in India. However, the preparedness of the Mumbai cruise terminal Port to act as an international cruise port is an understudied phenomenon with respect to the larger academic body of knowledge on the topic. The present paper attempts to fill the existing gap in the literature through the application of a benchmarking approach to assess the cruise readiness of the Mumbai cruise terminal Port.

The global cruise tourism industry has experienced a great transformation in the last two decades, evolving from a small-scale maritime industry to the substantial industry of international tourism and port development. In this sense, cruise ports have become "something else" from being just a transit point for the cruise vessels, but rather a relevant sector of cruise tourism, defined by the integration of the maritime, urban planning, tourism, and institutional factors. While the traditional cruise ports, such as Miami and Barcelona, are still setting the standards for cruise operation efficiency and sustainability, newly emerging economies are trying to enter this highly profitable global industry of cruise tourism operations. India, despite being situated in a strategic position on the international shipping line with a coastline of over 7500 km, has been on the periphery of the global cruise tourism industry. However, the current policy environment characterised by the implementation of the Maritime India Vision 2030 and the Cruise Bharat Mission seems to indicate the paradigm shift towards positioning India as the major destination for ocean cruises as well as river cruises.

The present study is guided by an exploratory qualitative method of evaluation and attempts to evaluate the preparedness of Mumbai cruise terminal Port to compete at the mature international cruise hub. By benchmarking the newly commissioned Mumbai International Cruise Terminal (MICT) against the established global leaders in the industry, the study tries to look at the critical interfaces of infrastructure sufficiency, governance, and port city integration. This is predicated on the understanding that whilst the infrastructure is an essential requirement in port city integration, this is not an adequate measure. Instead, the real measure of port city competitiveness can be found in the interfaces of port operations and the capacity of the port city to seamlessly integrate with the rest of the urban and economic fabric of the destination city. In a detailed analysis of the footfalls and recent developmental milestones in the cities of Mumbai cruise terminal, Miami and Barcelona, the present study is an in-depth evaluation of the challenges and opportunities that the Indian cruise industry is set to face in achieving the ambitious targets set for the years 2030 and 2047.

Literature Review

Cruise tourism is now one of the fastest growing segments of the tourism industry. It has done a lot with economic development, job creation, and growth in different areas. Various studies on tourism-led growth have indicated that tourism growth has a positive impact on national economic growth as it can increase the foreign exchange earnings and growth in related sectors such as hospitality, transportation, and related services (Tiwari, Singh, & Hussain, 2018). It is in this background that cruise tourism has come into limelight facilitating the development of port-led growth. In terms of cruise ports, it has been noticed that cruise ports all over the world have progressed from being simply a transit point of cruise passengers to being a hub for tourism activities to link maritime activities and urban tourism. According to Brida and Zapata (2010), cruise tourism has various impacts on the host destinations such as economic, socio-cultural, and environmental impacts. The economic impacts include increased expenditure in the local economy by cruise passengers, whilst the

socio-cultural impacts include changes in the lifestyle of the host communities, as well as interactions between the tourist and the host communities.

In the context of India, the development of cruise tourism has traditionally been at a low ebb despite the country having a long coastline and strategically located geography. Various researchers have pointed out that India holds a tremendous untapped potential in the development of cruise tourism because of the rich cultural diversity as well as the growing tourism market from the growing middle class in the country (Chawla, 2017).

Recent policy reports also highlight the growing importance of cruise tourism in the context of India's Blue Economy strategy. The Blue Economy is a new economic concept that has been described as "the sustainable use of marine resources to achieve economic growth, protect the marine environment, and promote social development" (Sulthana, 2025). In this context, cruise tourism is seen as a new economic opportunity that has significant potential to promote sustainable economic activities in the marine sector. Despite all these new opportunities, literature on the subject has consistently identified that one of the most significant hurdles faced by the cruise tourism industry in India is the lack of appropriate infrastructure. Verma & Sharma (2023) argue that one of the main hurdles faced by India in attracting large international cruise ships is the lack of appropriate cruise terminal facilities. Nevertheless, it has been noted that these policy developments have not been accompanied by the elimination of various governance issues in the maritime sector in India, by scholars. As an illustration, fragmented structures in the maritime governance, or even overlapping institutional domains are issues that impede the efficient application of the maritime policies in India (Sulthana, 2025). In an alternative study, Chatterton (2022) has divided the issues of cruise tourism development in India into problems in infrastructure, regulatory and promotional issues and made it clear that the institution coordination plays a key role in the issue. Research on cruise ports of different countries in the world has shown that effective cruise ports are the ones that are ruled by integrated structures which aim at balancing the interests of different stakeholders in the sector. This has been a significant issue in India, since there are no integrated structures in the governance of the cruise ports in India. However, the development of tourism activities can also result in socio-cultural issues in the local communities. Research on the tourism impacts in coastal areas revealed that tourism can provide economic opportunities but can also cause cultural change, overcrowding, and environmental pressures (Gokhale, Sawant, & Ugavekar, 2014). Therefore, the integration of ports and cities can be done with the consideration of the local communities' needs and interests.

The scholarly discussion of cruise tourism focuses on it as one of the drivers of port-led development. Tiwari, Singh, and Hussain (2018) present empirical data to support the strong correlation between tourist arrivals, tourism receipts, and long-term economic growth in India to validate the hypothesis of tourism-led growth, and although the potential is immense, the industry has been long hampered by poor infrastructure and lack of a clear national policy, which the Maritime India Vision 2030 is now intended to address.¹ The idea behind the Blue Economy is the key to the interpretation of the maritime ambitions of India. According to Sulthana (2025), sustainable utilisation of ocean resources such as coastal tourism has great prospects of inclusive development, but broken governance is a major challenge.¹ In the case of Mumbai cruise terminal, eastern waterfront redevelopment is a paramount effort towards port-city integration. Surve and Mhatre (2019) suggest transforming the industrial docks that are not actively used, including the Princess Dock, into dynamic ferry ports and tourist venues to reduce congestion in the city and active access to the coastline by the community.¹ This idea is reflected by Sandesh (2023), whose work on the architectural design of the Mumbai cruise terminal International Cruise Terminal focuses on the necessity of having facilities that are both transit hubs and public spaces throughout the year. Although the picture is looking good, scholars spot huge

bottlenecks. Verma and Sharma (2023) believe that the key barriers to the competitiveness of India are the poor berth infrastructure and the absence of any specialized cruise-handling facilities; they also believe that only a comprehensive approach could help India realize the potential of the sector and help the local community welcome the changes that seem to be inevitable with the development of the cruise industry.¹ Inadequate infrastructure also concerns the issue of the competitiveness of ports and berths in the country; Gokhale, Sawant, and Ugavekar (2014) state that, although the cruise. Mumbai cruise terminal International Cruise Terminal (MICT) which is at Ballard Pier and in the Indira Dock is the main infrastructure project that India hopes to achieve through its cruise ambitions. The terminal, commissioned at around ₹556 crore (over \$60 million), opened on September 23, 2025, by Prime Minister Narendra Modi, and is expected to be used by one million passengers per year, having already been used in April 2025 to make a series of high-profile domestic and international calls.

Infrastructure and Capacity Specifications of MICT

Feature	Detailed Specification
Terminal Area	415,000 Square Feet ⁷
Total Investment	₹556 Crore (approx. \$60.5 Million) ⁶
Annual Passenger Capacity	1,000,000 Passengers ⁶
Daily Throughput Capacity	10,000 to 15,000 Passengers ⁶
Simultaneous Berthing	Up to 5 Cruise Ships (300m length) ⁷
Check-in & Immigration	72 Counters (Ground & First Floors) ⁶
Ancillary Facilities	Shopping Mall, Convention Center, Yacht Marina ⁶
Parking Facility	300+ Vehicle Capacity ⁸

The design of the MICT includes a combination of contemporary maritime design and cultural elements with a wavy ceiling and "selfie points" for passengers.⁸ The management of the cruise terminal is done through a 30-year concession agreement by Ballard Pier Port Pvt Ltd and JM Baxi and Co, reflecting the worldwide trend towards the public-private partnership management of ports.⁶ The terminal's daily passenger handling capability of 15,000 passengers makes the Mumbai cruise terminal a gateway for the largest cruise vessels in the world, a considerable improvement from the former 25,000-square-foot terminal shed that served the port.⁶ Aside from its function as a cruise terminal, the terminal is designed to be a public space throughout the year with retail, entertainment, and restaurant options on the second and third floors of the terminal building. This is part of the strategy for the terminal's viability during the off-season for cruises.

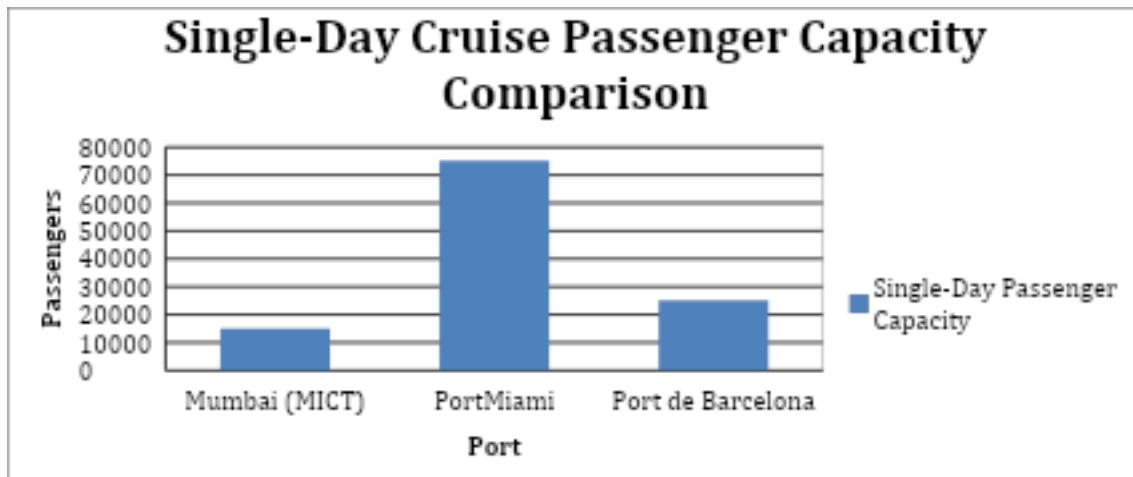


Figure 2: Comparison of single-day cruise passenger handling capacity across major international cruise ports.

This graph compares the operational passenger handling capacity of Mumbai cruise terminal International Cruise Terminal with two major global cruise hubs.

- The above comparison shows a huge difference in the operational scale between emerging and mature cruise ports.
- Moreover, Port Miami shows the highest capacity, with an ability to serve over 75,000 passengers in a single day, owing to its terminal infrastructure, digital processing capabilities, and the presence of multiple terminals.
- Whereas, Port de Barcelona shows a moderate capacity of 25,000 passengers per day, facilitated by specialized cruise terminals and passenger processing capabilities.
- The cruise terminal in Mumbai, a newly developed international cruise terminal, shows a maximum capacity of 15,000 passengers per day, a huge improvement over previous terminal infrastructure, though still lower compared to benchmark ports.

The results imply that the new terminal has greatly enhanced the cruise infrastructure of Mumbai cruise terminal but the port is required to increase the operational capacity, digital passenger processing systems, and intermodal connectivity to compete with other existing global cruise ports.

Passenger Footfall Trend Analysis: Mumbai cruise terminal vs. Benchmarked Ports

The passenger trend analysis of 2019-2025 shows that the recovery patterns after the global upheaval of the pandemic will be distinct. Whereas Port Miami and Barcelona have not just bounced back, but outgrown their pre-pandemic data, Mumbai cruise terminal cruise terminal faces a first growth spurt that has been spurred by its new facilities and a strong local market.

Historical and Comparative Cruise Passenger Traffic (2019–2025)

Fiscal Year	Mumbai cruise terminal (approx.)	Port de Barcelona	Port Miami
2019	468,000 (India Total)	3,100,000	6,823,816
2020	0 (Intl. calls susp.)	100,504	3,477,516

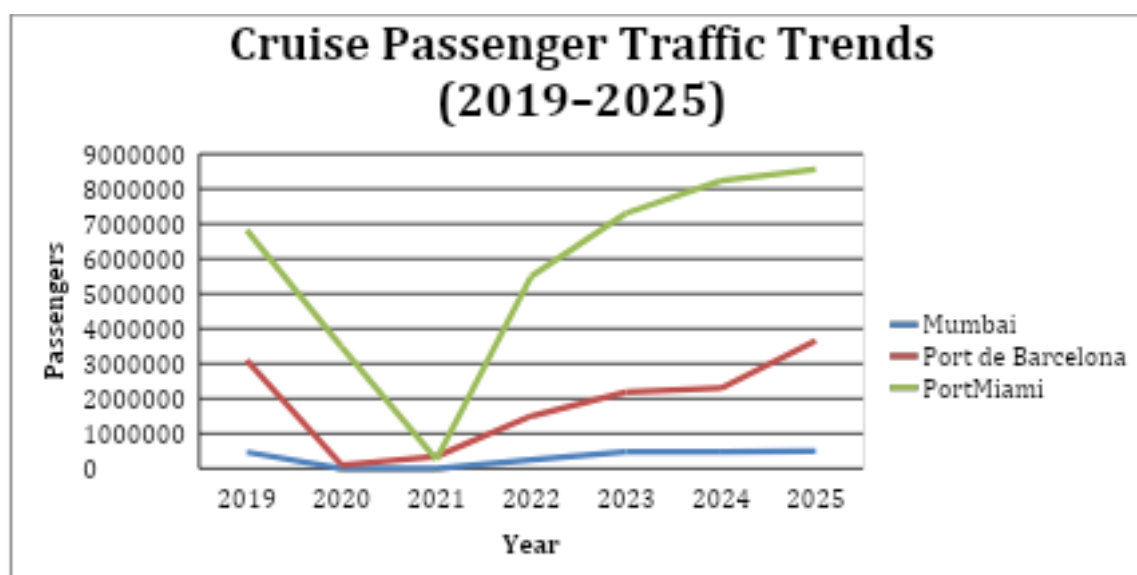
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2021	0 (Intl. calls susp.)	345,940	252,099
2022	250,000 (Post-COVID)	1,502,552	~5,500,000
2023	471,000 (India Total)	2,184,610	7,299,294
2024	471,000+ (FY 23-24)	2,295,454	8,233,056
2025	500,000 (Target Ph. 1)	3,655,981 (Movements)	8,564,225

The data underline that the growth of Port Miami in FY 2023 to FY 2024 was a 12.79% growth whereas the growth in FY 2025 was a 4% growth, which already demonstrated a new international standard of the volume of the cruise terminal.¹² For Mumbai cruise terminal, growth in the years 2023-24 only pushed the port to the all-time high with 20 international and 71 domestic calls. In Barcelona, the movements metric (counting embarkation and disembarkation) was 3.7 million in 2024, yet the cruise terminal has been focusing on the high-spending homeporting/high-capacity cruise liners in regular seasonal dispatches, which the cruise terminal in Mumbai must focus on to achieve the same economic outcomes. Newer news shows that ships of Celebrity Cruises, Silversea, Crystal, and Regent Seven Seas are to be rated in the 2024-25 season, and Cordelia Cruises is also increasing its fleet to ride on booming domestic demand.

Figure 3: Cruise passenger traffic trends comparing Mumbai cruise terminal, Port de Barcelona, and Port Miami (2019–2025).

Year	Mumbai cruise terminal	Port de Barcelona	Port Miami
2019	468000	3100000	6823816
2020	0	100504	3477516
2021	0	345940	252099
2022	250000	1502552	5500000
2023	471000	2184610	7299294
2024	471000	2295454	8233056
2025	500000	3655981	8564225



The graph illustrates the comparative passenger traffic growth of Mumbai cruise terminal, Port de Barcelona, and Port Miami from 2019 to 2025.

- The trend displays a severe disruption in cruise tourism during 2020–2021 due to the global COVID-19 pandemic, with passenger traffic declining sharply in most ports, while Barcelona showed a gradual recovery instead of a complete drop. Mumbai cruise terminal had a full-scale suspension of international cruise operations in the course of this time leaving the passenger traffic virtually zero. The overall trend of all ports starting in 2022 is a robust recovery pattern at varying levels. Port Miami demonstrates the largest recovery, going beyond the levels at the beginning of the pandemic and breaking through the mark of more than 8.5 million passengers by 2025, consolidating its status as the world leader in cruise operations.
- Port de Barcelona is another example of a gradually returning trend, with the movement increasing by more than 3.6 million passengers in the years 2025, after a decline in 2022 to 1.5 million passengers.
- Mumbai cruise terminal is not only recording good growth, but it is still way much smaller than the benchmark ports. The numbers of passengers are projected to grow slowly after 2022 up to an estimated 500,000 passengers by 2025. This is to denote that Mumbai cruise terminal is in a nascent growth stage, which has been greatly facilitated by local cruise demand as well as the development of the Mumbai International Cruise Terminal. As in the graph, although Mumbai cruise terminal has started gaining momentum and growing its cruise business, there remains a lot of capacity and operational distance against other major cruise centers around the globe.

Digitalization and Operational Efficiency

One issue that is vital in determining the competitiveness of a cruise port is operational efficiency. This has been achieved by Mumbai cruise terminal through the introduction of revised Standard Operating Procedures (SOPs), which has entailed the simplification of customs and immigration processes, and also through the introduction of a single-window system, however, mature hubs still have the advantage of more sophisticated biometric and integrated operating platforms.¹

To facilitate fast flow of the passengers, especially on peak turnaround days when 10,000 to 15,000 passengers can be served in a day, the MICT must be well-equipped with

72 counters to handle passengers speedily. To be able to manage the high volume of passengers; particularly on peak turnaround days, Port Miami is the first seaport to install a U.S. Customs and Border Protection Global Entry Enrollment Center to support the operation of the facility with high speed.

Comparison of Operational Parameters (2024)

Parameter	Mumbai cruise terminal cruise terminal (MICT)	Port Miami	Port de Barcelona
Single-Day Max Capacity	~15,000 Pax ⁸	75,201 Pax ²¹	~25,000+ Pax (est.)
Immigration Facilities	72 Counters ⁸	Global Entry Center ¹⁵	Biometric Gates
Turnaround Time (Avg)	62.97 Hours (All) ³⁰	<12 Hours (Cruise)	<10 Hours (Cruise)
Shore Power Availability	Early Implementation ¹	5 Operational Berths ¹²	Substation Arrived 2024 ²⁶

Although the average vessel turnaround time at Mumbai cruise terminal cruise terminal has increased by 67.42 hours in 2022-23 to 62.97 hours in 2023-24, it includes cargo and oil ships, whereas cruise turnaround is significantly smaller, and the overall efficiency parameters of the port (Ship Berth Day Output) have reached an all-time high in 2023-24.

Governance framework and institutional maturity

The primary discovery of the exploratory analysis is that the shift towards a mature (as opposed to immature) cruise terminal in Mumbai cruise terminal cruise terminal is impeded by the fragmented governance known as the fragmented governance.¹ At present, the cruise operations in the Mumbai cruise terminal cruise terminal Port Authority (MbPA), Customs, Immigration, the Central Industrial Security Force (CISF), and many state tourism and municipal departments are involved in cruise operations in the area. Conversely, more well-integrated governance systems in such mature hubs as Port Miami and Barcelona exist. The activities of Port Miami are well co-ordinated with Miami-Dade County leadership, and thus, cruise terminals development is co-ordinated with transport and economic development in the region.¹⁵ To reflect this success, the cruise terminal of Mumbai needs a specific cruise coordination mechanism to ensure that cruise, tourism, custom, and urban core stakeholders are integrated into a single strategic vision.¹ The adoption of the concept of public-private partnership (PPP) when managing MICT is a good move towards the global governance principles.⁷ The port will be able to use the global knowledge of how to operate, as well as the capital of the experienced personnel in the hands of JM Baxi. Nevertheless, regulatory landscape (high port tariffs and complicated clearance procedures) continues to be a problem to the foreign operators.⁴ The issue of these macro-policy barriers needs to be addressed to realize the full potential of Cruise Bharat Mission.⁴

Port–City Integration and the Urban Waterfront

Mumbai cruise terminal cruise terminal has a critical gap in physical and social integration of port into the city. Although located centrally, the MICT has minimal connections of last-mile connectivity to the greater urban transport systems in Mumbai cruise terminal cruise terminal.¹ Comparative examples demonstrate that a global cruise hub must have smooth connectivity to global airports, high-speed rail, and local transport. The cruise

passengers, which occupy about 15 percent of the total number of passengers at the international airport, indicate the high intermodal synergy in Miami.³² The method of integration in Mumbai cruise terminal revolves around the redesigning of its eastern water front. The suggested Marina project around Princess Dock and conversion of old port land into open recreational spaces are expected to build a dynamic land-sea interface.⁶ Re-use of these under-used spaces can offer greatly desired open recreational spaces and reduce congestion within the city as well as the overall passenger experience. In the case of Mumbai cruise terminal, a successful integration also implies that the social effects of the traditional coastal inhabitants, including local fishermen who might be displaced or restricted in their access because of extensive port developments, are managed.

Research Methodology

This research adopts an exploratory research design based on secondary data analysis.

Data Sources: Data were collected from:

- Government policy documents
- Port authority reports
- Academic journal articles
- industry reports
- architectural and planning studies
- international case studies of cruise ports

Comparative Analysis of Cruise Hub Readiness

Cruise Infrastructure and Terminal Capacity: The Mumbai cruise terminal International Cruise Terminal is one of the significant improvements in the cruise infrastructure, India. The modern passenger handling systems and multi-ship berthing capacity were added to it so it could have the capacity of serving up to one million passengers each year. Although this is being done, there are global cruise ports like Miami and Barcelona which are a lot bigger in size and provide more specialized cruise facilities. The research has shown that a low capacity of the berths and the lack of cruise specific facilities have put a limit on the capacity of India to receive large international cruise lines.

Passenger Facilitation and Operational Efficiency

Operational efficiency is a critical determinant of cruise port competitiveness. Mumbai cruise terminal has introduced several improvements, including:

- Digital clearance systems
- Simplified immigration procedures
- Single-window clearance mechanisms

These initiatives have reduced passenger processing times and improved operational efficiency. However, major international cruise hubs employ advanced technologies such as biometric boarding systems and integrated digital platforms that enable faster passenger processing and vessel turnaround.

Governance Frameworks and Institutional Coordination: The project of creating cruise terminals in Mumbai cruise terminal is based on the principles of the public-private partnership (PPP), according to the international tendencies in the management of ports. Nevertheless, there is a lack of institutional coordination between major stakeholders such as customs authorities, tourism agencies, municipal authorities and port authorities. On the

contrary, the Cruise hubs which are already mature are governed by combined governance frameworks enabling the integration of planning and effective management of operations.

Port–City Integration and Urban Mobility :Port–city integration remains one of the most significant challenges in Mumbai cruise terminal's cruise ecosystem.

Although the cruise terminal is located near the city center, several limitations persist:

- inadequate last-mile connectivity
- congestion in surrounding urban areas
- limited integration with public transport networks

International ports of call often feature purpose-built transport corridors, waterfront development areas and co-ordinated destination management plans in order to handle high numbers of passengers.

Sustainability and Environmental Stewardship: Cruise port competitiveness has been dominated by the environmental sustainability dimension, in which Mumbai cruise terminal has initiated the use of green port initiatives like shore power plants and environmental management systems. Nonetheless, these are still in their initial phases as compared to the top cruise destinations which have implemented high-tech solutions that comprise:alternative fuels:

- emission reduction systems
- comprehensive environmental monitoring frameworks

Research Gap

Despite the increasing interest in cruise tourism, there are still a few gaps in the literature. The systematic reviews show that there is a lack of research on the sustainability practices, technological innovation, and crisis management in cruise tourism. According to numerous works in the Indian context, infrastructure shortage is the main limitation to the development of cruise tourism. Nevertheless, fewer researchers consider larger institutional and city integration problems that affect cruise hub development. The current study will be relevant to the existing literature by a thorough analysis of Mumbai cruise terminal preparedness to operate as an international cruise destination where infrastructural, institutional, and urban integration viewpoints are also included.

Findings

The analysis shows that there will be a progressive increment in the number of passengers in three phases of the mission that portrays the desire of the government in developing the cruise tourism sector of India in a big way.

Phase I (2025) has a target of 1 million total cruise passengers, half of whom are sea cruise and half river cruise. The major aim of this phase is to enhance the basic infrastructure and enhance regulatory systems.

In Phase II (2027), the number of passengers should reach 1.7 million, and the river cruising passengers will grow significantly. This indicates that inland waterways are being considered as a significant element in the tourism policy of India.

At Phase III (2029) the overall passenger target increases to 2.5 million and the river cruise tourism is estimated to hit 1.5 million passengers compared to the sea cruise volumes. This shows diversification of the cruise industry, as it combines tourism routes that are coastal and inland.

Discussion

This paper has found out that the Mumbai cruise terminal Port is in the midst of a massive change in the wider framework of the strategy of developing maritime India. The opening of the Mumbai cruise terminal International Cruise Terminal (MICT) is a significant developmental infrastructural step in indicating that India is willing to be more involved in the cruise tourism network at the international level. Nevertheless, in a comparative analysis with the established international cruise hubs, the changeover between an emerging cruise port and an international cruise hub is not only physical infrastructure but also institutional maturity, operational efficiency, integrated governance structures and practices of sustainable development. These dimensions are discussed in more detail below.

Infrastructure Development and Global Competitiveness: Infrastructure is among the most important factors of cruise hub competitiveness. The opening of the Mumbai cruise terminal International Cruise Terminal has boosted the capacity of cruise infrastructure in India in a great way. The terminal is capable of accommodating about one million passengers each year, and this will, therefore, be a significant enhancement of the limited cruise facilities that were in use in the country before. A well-developed passenger handling infrastructure, multiple berthing facilities and improved terminal facilities give the cruise tourism at Mumbai cruise terminal a solid base to grow. Nonetheless, even with these developments, there are still some major gaps when Mumbai cruise terminal is compared to other global cruise markets like Miami, Barcelona and Singapore. These are ports which are run on a grander scale, which can carry a few million cruise passengers every year and can carry a number of mega cruise vessels at the same time. Besides their physical size, major cruise ports have infrastructure built specifically to accommodate high-volume cruise operations with high-level baggage handling, dedicated cruise terminals, integrated logistics, and effective intermodal connectivity.

Governance and Institutional Coordination: The effectiveness of cruise port development strategies is dependent on the form of governance in place. The results of this research show that despite various policy initiatives that have been implemented in India to ensure the spread of cruise tourism like the Maritime India Vision 2030 and Cruise Bharat Mission, there are still considerable implementation problems since institutional arrangements have not been put together. The development of cruise infrastructure of Mumbai cruise terminal pursues the model of the public-private partnership (PPP), which signifies the trends in port management across the world. The PPP arrangements are so popular in the cruise industry as the governments can take advantage of the investments and expertise provided by the private sector without losing control over them. Theoretically, this model of governance would help enhance operational efficiency, promote innovation, and decrease the burden on the public authorities in terms of finances.

Port–City Integration and Urban Connectivity: Among the most notable results of this research, the fact that the connection between the cruise terminal and the surrounding urban environment is limited should be named. The concept of port-city has come to dominate the modern planning of the sea as contemporary port is becoming more connected to urban economies, tourism areas, and transport infrastructures. The Mumbai cruise terminal International Cruise Terminal is also located in close proximity to the city center and as such, this theoretically gives it great benefits in terms of cruise tourism development. The terminal is well-positioned to allow passengers who come to the terminal to access key tourist destinations, business and cultural places in the city. This distance has been a source of competitive edge over other ports which are located far away. However, there are a number of issues that inhibit the efficiency of this locational advantage. Among the most noticeable ones is the lack of last-mile connectivity in the cruise terminal and leading transportation systems like airports, railways, and urban transport systems. The current transportation system in Mumbai cruise terminal is already strained by the high human population density,

as well as excessive traffic. These problems may indeed be aggravated by the fact that with the introduction of massive amounts of cruise passengers, proper transport planning was not established. The examples of other countries of the world show the necessity of interconnection of cruise terminals with the urban transport network. Large cruise terminals will typically offer special shuttle service, built-in metro access or transit organization to facilitate ease of passenger movement. Other ports have also created waterfront promenades, tourism districts and mixed-use developments that are continuous between the port and the urban environment. Some of the proposals presented in the case of Mumbai cruise terminal like proposing that Princess Dock be transformed into a ferry terminal and a tourism center can demonstrate how waterfront revitalization projects might enhance port-city integration. These projects may establish new spaces in the community, encourage tourism business, and make the waterfront more appealing in general. When achieved in an efficient way, waterfront development might make the port area in Mumbai cruise terminal a dynamic tourism hub that will supplement cruise activities.

Sustainability and Environmental Responsibility: Environmental sustainability has been seen as a major determinant of the future of global cruise industry. There is a growing pressure on cruise ports to implement environmental friendly activities that minimize emissions, safeguard marine organisms, and mitigate the environmental impact of the cruise activities.

Moreover, sustainable cruise tourism does not just involve environmental control at the port but also long term plans that take into consideration the environmental effects of tourism activities in the destination city. The problems like overcrowding, waste disposal and strain on the local ecosystem should be effectively regulated so that in the long run, the development of tourism becomes sustainable.

Technological Innovation and Digital Transformation: Another factor that affects the competitiveness of cruise ports is technological innovation. Digital technologies are becoming more and more significant in the field of increasing the efficiency of operations, improving passenger experiences, and increasing the security procedures.

Mumbai cruise terminal has initiated a few digital programs such as electronic visa programs and digital clearance systems of cruise passengers. These have greatly shortened the processing time as well as made administration processes easier. Numerous world cruise ports have however gone a step further to full digitalization ecosystems that include biometric identification systems, automated boarding processes and real-time data management systems.

Strategic Positioning of Mumbai cruise terminal within the Regional Cruise Network: The other fact which the current research has highlighted is the strategic geographical location which Mumbai cruise terminal enjoys in the Indian Ocean cruise network. As one of the main shipping routes of the world, Mumbai cruise terminal can be used as a key gateway between the South Asian region and cruise programs along the Middle East, Southeast Asian and Indian Ocean regions. It is projected that regional cruise tourism will increase greatly over the next few decades as the emerging markets in Asia create more and more demand of leisure travel. Domestic cruise tourism is also rising due to the growth in the number of Indian middle class and increased disposable incomes.

Strategic Key Performance Indicators: Cruise Bharat Mission (2025–2029)

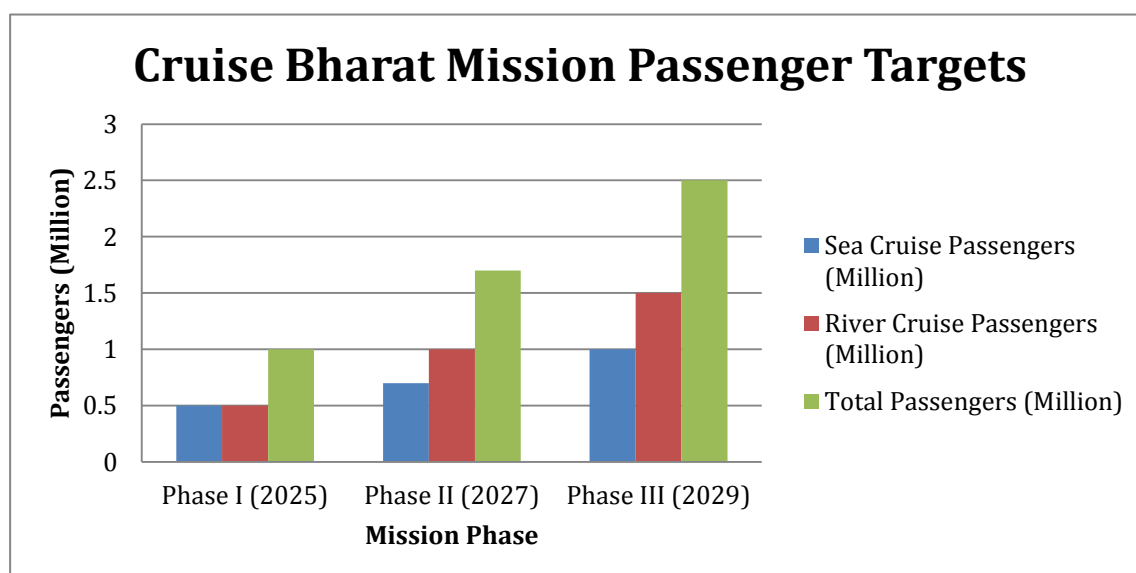
Key Performance Indicator	Phase I (To 30.09.2025)	Phase II (To 31.03.2027)	Phase III (To 31.03.2029)
Sea Cruise Passengers	0.5 Million	0.7 Million	1.0 Million

River Cruise Passengers	0.5 Million	1.0 Million	1.5 Million
Total Combined Passengers	1.0 Million	1.7 Million	2.5 Million
Sea Cruise Vessel Calls	125	250	500
International Cruise Terminals	2	5	10
River Cruise Terminals	50	75	100

Institutional maturity of the sector is also witnessed through the application of cruise-friendly policies which includes the rationalization of port tariffs, the introduction of single-window clearance, and the introduction of e-visa in key cruise ports which have played a vital role in making the area take off to international cruise operators.

Figure 2: Passenger growth targets under the Cruise Bharat Mission (2025–2029).

Phase	Sea Cruise Passengers (Million)	River Cruise Passengers (Million)	Total Passengers (Million)
Phase I (2025)	0.5	0.5	1
Phase II (2027)	0.7	1	1.7
Phase III (2029)	1	1.5	2.5



This graph demonstrates the government's strategic growth targets for cruise tourism under the Cruise Bharat Mission (2025–2029). The graph shows that the Indian government has a long-term policy commitment to build cruise tourism as a part of the Blue Economy, where infrastructure development, policy changes, and tourism circuit development are of primary importance.

Managerial Implications

Managers should improve stakeholder coordination to enhance cruise operations. Infrastructure development must include transport connectivity and tourism services. Adoption of digital technologies can improve efficiency and reduce delays. Strong port–city integration is essential for passenger convenience. Focus on sustainability and effective public–private partnerships will help Mumbai develop into a competitive international cruise hub.

Conclusion

Evaluation of the Mumbai cruise terminal as an international cruise hub indicates that it has immense potential along with structural challenges. The commissioning of the Mumbai International Cruise Terminal provides a strong physical structure that is capable of handling a million passengers per annum and competing with the best in the region in terms of physical infrastructure. The national policy environment, led by the Cruise Bharat Mission, provides a conducive structural environment that has already led to an increased passenger footfall and vessel calls.

However, the comparative evaluation with Port Miami and Barcelona indicates that the Mumbai cruise terminal is still short in terms of institutional maturity, port-city interface, and environmental technology. The Mumbai cruise terminal handles a fraction of the passengers that Port Miami handles 8.5 million passengers per annum with a high level of synchronicity in the intermodal interface whereas the former is still struggling with the regulatory environment and connectivity with the city. The move from an emerging port to a mature port requires more than just physical infrastructure; it requires a service ecosystem. Mumbai cruise terminal faces lower passenger traffic due to several operational and structural limitations. The terminal has limited berth capacity, restricting the number of cruise ships that can be handled simultaneously. Poor last-mile connectivity and heavy urban congestion reduce passenger convenience. Fragmented governance among multiple agencies leads to delays in clearance and operations. In addition, the cruise ecosystem is still developing, with limited tourism integration and support services. Advanced digital passenger processing systems are also not fully implemented, which increases turnaround time. These factors collectively reduce Mumbai's competitiveness compared to established global cruise hubs.

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Contemporary Trends in Freight Forwarding Operations in India

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Abstract

The freight forwarding industry plays a key role in managing internationalised supply chains, especially within emerging economies that are characterised by infrastructure-intensive logistics systems. In the Indian economy, prevailing policy reforms, technological developments, and planned developments to establish Multimodal Logistics Parks (MMLPs) have created significant changes to the freight forwarding industry. In the present study, the researcher has employed the qualitative dominant exploratory research design model for its suitability in understanding the present trends of freight forwarding operational activities, particularly concerning the digitalisation process in freight forwarding, the transformation of its operations, and the emerging trends of MMLPs. Relevant primary data were obtained from semi-structured interviews with about 10 freight forwarding professionals across India's freight forwarding sector. In addition to the above, an extensive study of secondary literature has also been made. The present study finds that digital technologies play an important role as coordination mechanisms for achieving greater operational transparency. Furthermore, the capability of various government initiatives can be viewed as structural enablers of greater modal transport integration and lower transport costs. The study contributes to the logistics and supply chain management literature by empirically linking freight forwarding operations with digital transformation and multimodal infrastructure development in an emerging economy context. Managerial and policy implications are discussed to support industry stakeholders and policymakers in strengthening India's freight forwarding ecosystem.

Keywords: Freight Forwarding, Multimodal Logistics Parks, Sagarmala, National Logistics Policy.

Introduction

Logically, effective systems of logistics and the supply chain form the bedrock of international competitiveness in the domain of trade, especially at the onset of and within emerging economies, where the hurdles of infrastructure and institutions seem most apparent. Indeed, the phenomenon of freight forwarding assumes a central role within the dynamics of the entire supply chain. Logically, in the case of the Indian subcontinent, whose logistics costs are far from negligible and whose transport infrastructure is fragmented multimodally, freight forwarders function both as mere intermediaries and as those of the operation itself. The Indian logistics sector, too, has undergone an impressive evolution during the past ten years, with an increase in intra- and intertrade volumes, an increase in the involvement and participation of micro-small and medium-scale industries in international trade, and extensive initiatives by various Indian governments to develop and expand Indian infrastructure. Various Indian government programs and policies include the National Logistics Policy program, the PM Gati Shakti program, Bharatmala, Sagarmala programs, and the Multimodal Logistics Parks.

Despite these developments, challenges remain for freight forwarding operations in India. Challenges such as infrastructure, customs, and technology adoption, especially for small- and medium-sized freight forwarding operators, are prominent. So far, previous research has focused on issues such as logistics performance, multimodal transportation, and digitalisation separately, while little attention has been paid to how these elements

combine to affect freight forwarding operations from an operational perspective. This study seeks to fill this research space by focusing on the latest trends in freight forwarding in India, adopting a qualitative-dominant empirical approach. The study will aim to explore the impact of the digital wave and the newly unfolding MMLP construct on the very operations, coordination systems, and services within the broader logistics and supply chain management system. The industry-level approach of the proposed research will offer insights into the potential enabling and inhibiting factors within the emerging economy framework.

Literature Review

The EY, 2023 report discusses India's aspirations to reach a \$26 trillion economy by 2047, with logistics contributing to this mission. Today, the focus is on technology – artificial intelligence, blockchain, digital freight platforms, sustainable logistics, infrastructure development – Bharatmala, Sagarmala, and Dedicated Freight Corridor. However, even with all this, issues of fragmented models, road-based logistics, and lack of end-to-end visibility still linger. It has suggested private sector cooperation to reduce logistics costs from 13-14% of GDP to 8-10% of GDP by 2030. K. Antony Saron & Dr. A. Meera (2024), The empirical study focuses on the challenges faced by freight forwarders based on the aspects of documentation, customs, freight operations, and communication, particularly in the region of Chennai. According to this study, there is a significant relationship between the type of cargo, mode of transport, and shipping frequency. Delays, complexities, and the lack of stakeholder management have been identified with suggested solutions of digitalisation. The assessment of the challenges and other influencing factors prevailing in the freight forwarding industry by taking the case of Freightkare Multimodal Logistics Pvt. Ltd., Chennai. The study indicates that regulatory compliance, technology, and economic issues are the challenges that need to be addressed through continuous technology upgrades and/or workforce training and upgrades.

Saron & Meera (2024) emphasised how packages were damaged (40%), and delays in shipment (32%) were prominent issues faced during freight forwarding. Similar findings were corroborated, highlighting how regulatory issues, coordination, and documentation were significant barriers, thereby proving the need for digital infrastructure and policies. Integrated multi-modal transportation systems have gained momentum as a promising strategy to address urban congestion, increased mobility needs, and cost control. A multi-modal system integrates various transport mediums to efficiently address the need for a sustainable transportation system. Benefits of a multi-modal system include reduction of travel time, improved accessibility, effective use of land, and a reduction of greenhouse gases. The Gati Shakti Master Plan, freight corridors, and the development of intermodal terminals have emerged as important avenues to accelerate national competitiveness and strengthen infrastructure.

Objectives

- (i) to examine recent operational trends in the Indian freight forwarding sector;
- (ii) to analyse the influence of digital technologies and government-led infrastructure initiatives, particularly MMLPs, on freight forwarding operations; and
- (iii) to identify key operational challenges and emerging opportunities shaping the future of freight forwarding in India.

Research Methodology

Research Design and Approach

The research study employed in this qualitative (interview) exploratory research study is intended to examine contemporary freight forwarding industry trends within India. The

applicability of qualitative research, based on its approach, can be attributed to the nature of the research problem, where it captures not only operations and challenges but also institutional influences. Freight forwarding operations take their shape based on the mixture of market forces, rules, and infrastructure, making it appropriate for qualitative research.

In essence, the Indian logistics scene, when viewed through the policy filter, is at present undergoing a process of structural change with substantial-scale government interventions such as the rollout of the National Logistics Policy, the launch of the PM Gati Shakti program, and the planned development of Multimodal Logistics Parks. However, it is quite evident that such interventions are currently at different stages of implementation. Consequently, freight forwarder operations under such scenarios can never be said to be stable. In such situations, exploratory qualitative research can help draw views not necessarily captured through any of the quantitative or secondary data parameters.

Rather than testing any connections, the study aims to explore patterns, perceptions, and operational responses from freight forwarding professionals. This is also in line with recent calls within logistics and supply chain research for a greater use of qualitative methods when studying institutional change, policy implementation, and the adoption of technology in emerging economies.

Data Collection and Sampling

The primary data collection methods were through semi-structured interviews of around 10 freight forwarding professionals who work through all the major hubs of India. The participants were professionals who included senior managers, operations managers, and business owners of small, medium, and large-scale freight forwarding organisations. The selected participants were diverse to ensure consideration of the results of such policies and technological interventions on different scales of firms. The interviews were held across various points that play a strategic role in India's logistics landscape. This includes ports and clusters associated with ports, inland container depots, and emerging clusters related to logistics corridors. The respondents involved in these interviews participated in activities that involved direct interaction with policy influences. For instance, there was interaction with customs authorities, and the operations associated with digital platforms led by the government.

Role of Policy Context in the Study

Another instrument that is important for this study is public policy. However, it needs to be noted that it is more related to creating an environment wherein freight forwarding activities take place. The National Policy on Logistics and the policies implemented under the PM Gati Shakti program do, for a fact, address concerns related to multimodal integration, digitalisation, and cost reduction, and these have a practical bearing on the nature of freight forwarding activities that can be undertaken. The practical use of the intent of such policies, however, is not something that can happen instantly.

For instance, often in these interviews, there has been an apparent reference to elements such as port community systems, electronic documentation requirements, and possibilities regarding MMLP locations in terms of operational changes, which were used as part of a response. In that way, it can be said that by analysing these accounts of micro practitioners based on the context of the macro policy, it is possible to fill the gap that has existed so far between these two aspects.

Importantly, the study does not presume that policy interventions will result in an improvement of the overall efficiency of the system. It rather explores how freight forwarders react to-or sometimes wrestle with-policy interventions, particularly when digitalisation and infrastructure development do not evolve evenly.

Discussion

Data Analysis

Data analysis from the interview employed a thematic analysis approach through iterative and inductive procedures. Interview transcripts were read multiple times to identify themes recurring to operational change, technology use, multi-modal coordination, and policy interaction. Initial coding described categories that later got transformed into higher-order themes that reflected broader operational and institutional patterns.

While the analysis remained informed by prior literature on logistics and supply chain management, themes were allowed to emerge from the data rather than imposing pre-defined theoretical constructs. This helped to create a balance where findings would remain firmly anchored to practitioner experience while contributing to the academic discussion of freight forwarding and multimodal logistics in the face of digitalisation.

Particular attention was paid to variations in responses across firm size and operational scope, as well as to tensions between policy expectations and practical constraints. These nuances form an important part of the study's contribution, given the light they shed on the uneven and nonlinear nature of logistics transformation in emerging economies.

Interpretations

The results of this study show that India's freight forwarding industry operates within a developing, policy-driven logistics environment, where operational practices are increasingly influenced by drivers such as regulatory and institutional reforms. Unlike previous eras, when freight forwarding was more 'reactive' to the needs of the shipper and the availability of carriers (Tramp shipping), contemporary practices have been impacted by a series of "governmental initiatives".

The policy-embedded nature of freight forwarding is not specific to India; rather, how this phenomenon plays out varies significantly from one country to another. In the case of well-developed logistics infrastructure, such as that found in Singapore and European countries, freight forwarders can collaborate on implementing policies at the conceptual stage of developing digital platforms. In India, freight forwarders are most often on the receiving end of policy interventions in the form of operational constraints. This has resulted in freight forwarders in India playing a dual role, on one hand, they are simply the execution arm of national-level logistics reforms, focused in embracing changes like electronic documentation systems, adapting to customs procedures, and being compliant with multimodal policy objectives; on the other, they are buffers that help to compensate for institutional inefficiency while making such policies and ideas work. This latter role, of course, does not get as much attention in academic discourse as it may in terms of actual freight forwarding activity. Against the international practices, one of the sharpest contrasts to emerge from the findings relates to the role of digitalization in freight forwarding. In India, digital tools are mainly used to meet the requirements of regulatory frameworks, electronic documentation, customs filing, and compliance based on platforms. These, no doubt, help in bringing greater transparency and minimise manual errors; however, in the eyes of freight forwarders, these are operational imperatives rather than strategic enablers.

By contrast, freight forwarders in economies like the United States, Singapore, and parts of Europe use digitalization as a key driver of competitive advantage. E-freight forwarders in these countries offer platforms with integrated booking, tracking, customs brokerage, analytics, and customer communication. This allows forwarders to gain predictive insights, optimize routing decisions, and manage risk considering effective supply chains. Accordingly, freight forwarding becomes value-added coordination on a data-driven basis, rather than purely transactional in nature.

However, the Indian freight forwarding sector has found it hard to completely leverage the digital shift. Currently, while the bigger freight forwarding companies in logistics hubs are increasingly using cutting-edge integrated digital solutions, the freight forwarding industry in the country still largely has digital fragmentation. In the context of emerging countries, differing results were obtained with regard to regulatory digitalisation versus organisational digital capability. To be specific, the digital trend does not directly improve the performance of the logistics sector.

The comparative analysis also serves to illustrate the extent to which freight forwarders contribute to trade facilitation, especially within a regime marked by regulatory complexities. The role of freight forwarders is quite prominent within India, where, for instance, they have been accustomed to serving as a link between exporters and regulatory bodies, especially within the realm of customs regulations and the accuracy of relevant documentation, discrepancies of which prove problematic. This is especially true for MSMEs, whose internal capabilities may not be sufficiently advanced to comprehend trade complexities. In more advanced logistics infrastructures, such as in Singapore, there are appropriate structures that incorporate freight forwarders into the regulatory process through trade platforms. Here, the freight forwarders are not only compliant with the regulations; they also assist in the application of the laws and regulations by assisting in the usage of the platforms, including the structuring of data as well as optimization of processes. Firstly, it stands to reason that freight forwarders should be formally recognized as implementation partners in national logistics strategies. Furthermore, the experiences of the freight forwarders are critical both for pinpointing policy gaps and for implementation. Second, digitalization measures should go beyond mere compliance-oriented platforms to deliver interoperable systems to support freight forwarders in creating value, both operational and strategic, with a set of lessons learned from global best practices identifying the value of single windows, data standards, and platform co-creation. Third, policy guidelines must consider the issue of coordination burdens on intermediaries. Dealing with redundancy, harmonization, and collaboration can greatly improve efficiency in freight forwarding services without any capital cost.

The current research develops the literature on logistics and supply chain studies through three key contributions: by re-conceptualizing freight forwarding as a coordination function embedded in policy, by highlighting the irregular translation of digital reforms into operational value, and by showing that intermediary roles vary across national contexts, as they incorporate practitioner perspectives into international comparisons. Rather than infrastructure-centric analyses, this discussion foregrounds the organizational and institutional dimensions of logistics transformation. It does so in line with emerging scholarly calls for greater attention to intermediary actors and their role in shaping supply chain performance, especially within the emerging economies. Conclusively, the integrated discussion shows that while there is a meaningful transformation in India's freight forwarding sector, institutional fragmentation and patchy digital integration impede its further substantial contribution to logistics efficiency. International comparisons show that freight forwarders contribute best when their businesses are integrated within cohesive digital ecosystems and are considered as valued strategic partners in trade facilitation.

Findings

From the analysis of the results on the use of qualitative data, there is an indication of an evolutionary but not complete transformation in the operations of the freight forwarding sector in India. There is an evident change in documentation, coordination, customer interaction, and dealing with regulatory interventions in the operations of the segment. However, there is no complete uniformity in the changes observed in the operations.

In every case, respondents are consistent in their observation that, currently, freight forwarding practices are significantly different from those that were five or seven years ago.

However, simultaneously, they also stress that, nevertheless, the speed of those changes depends on certain institutional, infrastructural, and capability-related limitations. Accordingly, freight forwarding practices are seen as having a “hybrid” character. The results are organized thematically because of the patterns as opposed to single observations. A prominent trend is the expansion of the scope of operations for freight forwarding companies. The respondents described a trend where the role of the freight forwarder is changing, though slowly, from a specific role in the execution of shipments to a more coordinated role. A freight forwarder now handles multiple interfaces simultaneously, ranging from shippers, carriers, customs, transport providers, and online platforms. In addition, many respondents indicated that because of changes in the sector, clients began to expect that freight forwarders would take end-to-end responsibility for certain activities, including documentation, inland movements, and regulatory matters. These are not new expectations, but their level and frequency are heightened. Despite this expansion, respondents made a distinction between responsibility and authority. As much as freight forwarders are required to deal with disruptions, they lack authority over institutional actors. Therefore, this situation results in complexity since the authority of freight forwarders is less than their level of accountability.

Digitalisation is one of the prominent themes that have emerged from the interviews. Though with varying levels of operational impact. Most respondents agreed that digitalisation technology is now integral to day-to-day freight forwarding tasks, especially for documentation submission, customs filing, and tracking. Electronic data interchange systems for documentation have helped mitigate paper dependency to a considerable extent. Despite all these, the respondents were unanimous that digitalisation has not replaced manual intervention. For example, some respondents felt that, despite digitalisation, manual document checks and follow-ups and coordination are still important mechanisms that govern the movement and clearance of shipments, mainly due to delays in the digital systems. Also, it is found that the level of adoption of digital tools varied by firm size. While the adoption of digital tools appeared to be more systemic in the case of large freight forwarding companies, smaller firms reported selective adoption. For example, smaller freight forwarding firms mainly adopted third-party agents to handle digital filings.

The results thus demonstrate that regulatory compliance is a key part of freight forwarders’ operational activities. Indeed, much of what freight forwarders told us reflected their experience and understanding of their role as ‘interpreters’ of, and ‘implementers’ of, regulatory requirements on behalf of their customers, and in that respect, their role has clearly intensified in line with more ‘digitized’ and ‘procedure-heavy’ regulatory regimes.

In terms of manifestations, such coordination efforts often involve multiple communication exchanges. For instance, freight forwarders said that they took considerable time coordinating with freight carriers, transportation service providers, ports, and authorities. These coordination efforts were described as critical to avoid cascading delays. While digital tools did somewhat enable the sharing of information, respondents also made it clear that, ultimately, coordination rested heavily on the relationship between people. This was especially true when dealing with exceptions, such as holds, paperwork issues, or schedule changes. From these results, it can be determined that there has been a considerable shift in terms of what clients expect, and they are searching for transparency, response, and predictability. Clients, as stated, are asking for timely updates, active communication, and faster resolutions. The freight forwarders accommodated these expectations by investing more resources into communication with customers. For many of the respondents, this was done informally, meaning these organizations did not design their processes formally. For instance, respondents talked about putting people in place to constantly follow up with customers. However, the pricing structure remained the same. The core issue here is that some of the respondents have pointed to a scenario wherein the value of services added is

not entirely commensurate with the compensation received. Indeed, the same problem emerged because of the increased competition in such market segments.

Firm size emerged as a significant differentiating factor in operational capability. Larger freight forwarding firms reported greater capacity to invest in technology, training, and process standardisation. Such firms were in a better position to absorb regulatory changes and operational disruptions. Smaller firms, while flexible in many areas, nevertheless relied on the availability of capital, the size of the workforce, and the availability of technological infrastructure. Most use personal expertise and informal networks to manage operations; scalability remains scarce. Freight forwarders developed accumulated experience, informal intelligence, and proactive communication that would have helped in forecasting the occurrence of disruptions and, in turn, devising mitigating strategies in advance. These practices were rarely formalized but widely recognized as key to operational continuity. Respondents also commented that risk exposure had gone up with increased procedural complexity. Though digital systems improved traceability, they also provided the possibility of new failure points that needed monitoring and contingency planning.

Managerial Implication

The results of this study have various implications regarding freight forwarding agencies, logistics service providers, exporters, and other stakeholders of the ecosystem, focusing on the context of India's international trade and logistics domain. The practical nature of these implications is an inherently desired trait, with reference to the operational reality that such businesses and stakeholders encounter regularly.

One of the most immediate implications for freight forwarding companies is to reassess and internally redefine how their role as freight forwarders is perceived. This is so because the study found that freight forwarders already carry out coordination and compliance as well as risk mitigation roles, which, by any measure, go beyond mere freight shipping. However, these roles are often not seen in that light.

Although technology adoption is important, the study found that software-related investments appear to have lower returns unless technology investments are supported by simultaneous investments in operational competency. This is because, ultimately, freight forwarding is a coordination-intensive activity that requires judgment, an understanding of the legislation, and soft skills. Some of the steps that can be taken by firms include training on how to understand regulatory guidelines, document compliance, and exception conditions. Such training is not only required for compliance teams, but also for operations teams and front-office personnel. Firms can develop capabilities in these areas, thereby becoming less dependent on informal means.

The results showed increased expectations regarding the responsiveness and problem resolution of the clients regarding the issues of visibility. There exists a disconnect between the expectations and the understanding of the complexity of the freight forwarding operation. This void can be filled by freight forwarders, who can actively ensure that their customers are educated on these procedural requirements, risk areas, and time frames. Open communication, especially in times of disruption, can go far in building and reinforcing trust; forwarders who take on advisory roles rather than execution-only operations are more likely to attract long-term customers, even in difficult times. One of the evident operational challenges, based on the study, is the issue of services received versus the compensation paid. Freight forwarders often assume more compliance efforts without the corresponding compensation reflected in pricing models.

From an industry viewpoint, it may well indicate a need to rethink how services can be priced. Competition from the market means that there may be only a limited scope in terms of pricing, although forwarders may be able to differentiate complex shipments using

consultancy or added packages. The findings of the article also illustrate the importance for exporters, especially MSMEs, of considering the role of freight forwarders as partners rather than service providers, since they often have a potential procedural and institutional influence that could reduce risk in international trade. Exporters can improve their outcome by engaging freight forwarders as early as possible, ideally before planning their contracts, rather than waiting until their contracts are signed. Exporters can benefit from improved route decisions, documentation, and compliance. Although it is necessary to rely on freight forwarders, exporters can gain from developing some general knowledge of procedures and documentation themselves. The quality of communication and the reduction of avoidable errors can be improved.

One of the most useful consequences of the concept relates to system interoperability. Indeed, freight forwarders must practically interact and work on various platforms with which diverse institutional roles must be associated. It is recommended that developers of platforms prioritize data integration and standardization. This will make it possible for information exchange systems to be seamless, hence aiding freight forwarders in providing quality services. Associations that represent the freight forwarding industry have historically been more focused on advocacy and regulatory representation. However, although these functions are obviously important, the findings suggest that a capability-oriented thrust is required.

Although this section has a focus on industry, a practical implication from a policy stakeholder perspective clearly arises: freight forwarders should be recognised as operational intermediaries rather than downstream users of logistics reforms. Engagement with freight forwarders throughout the piloting phases of both digital platforms and procedural changes allows for early identification of operational bottlenecks. This engagement results in better policy outcomes without structural change.

Conclusion

The aim of this present study was to investigate the present-day trends of freight forwarding, specifically in the Indian context, with reference to the larger discourse of logistics developments, government interventions, and changing modes of operation. Thus, this research, with a qualitative dominant approach, investigates the actual functioning of freight forwarding, rather than its assumed working based on policy or infrastructural interventions.

The results show that freight forwarding in India is during developmental change. It seems that freight forwarders are no longer viewed simply as executing agents, with limited roles in facilitating the arrangements of consignments and processing documentation. Instead, they seem to be viewed as coordination-intensive agents with roles in facilitating information flows, regulatory requirements, and inter-organisational coordination in a disintegrated supply chain environment.

The study, therefore, equally reveals that this evolution is not yet complete and is continuous. Thus, whereas digitalisation is noted to have changed existing processes and improved transparency, it has not successfully eradicated the need for manual interventions and practices of experiential judgement and coordination. Henceforth, we have digital platforms and traditional practices coexisting side-by-side, creating hybrid systems of operation through which freight forwarders must deal. The presence of such hybrid systems indicates that operational capability development cannot be ignored.

A key conclusion from this research is the emphasis on how freight forwarders, particularly in India, act as a system of complexity absorption. Tragically, they often end up carrying the load of complexities emanating from regulatory fragmentation, platform inconsistencies, infrastructural limitations, and even client readiness. By carrying this burden,

freight forwarders actually allow for continuity in trade, even if it means absorbing complexities that could have interfered with the trade process. However, this role has been largely invisible, particularly regarding their contributions to carrying on with supply chain continuity.

This comparative perspective, which is inherent in the study itself, further underscores that the value of freight forwarding can vary significantly. In developed countries, freight forwarders are part of a robust, seamless, technology-based institutional setup that assists them in leveraging the benefits of technology, delivering effective support in implementing policies, and creating and accumulating value. In contrast, freight forwarders in India are part of a fragmented institutional structure, in which every opportunity to undergo strategic transformation is inhibited by institutional and structural factors. This comparison needs to be seen as not implying any deficiency in terms of capability among Indian freight forwarders.

As a broader supply chain issue, the research reinforces the importance of intermediaries and their ability to translate ambitions into reality. Freight forwarders sit at the very core of the supply chain, between shippers, carriers, regulators, and digital platforms. The way they bring these components of the supply chain together is not only important to the effectiveness of services, but it is equally important to the inclusiveness and resilience of trading systems. The importance of acknowledging the position and role of these freight forwarders lies at the heart of ensuring that the ambitions and objectives expressed in national logistics strategies can be achieved.

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Factors Affecting the Process of Ship Recycling in India

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Abstract

Ship recycling or the disposal of ships is a critical stage in the total lifecycle of a ship. The yard of the Alang and India in general have emerged as the leading ship recycling avenue in the world, which can be explained by its economic feasibility, the huge quality of its labor forces, and advanced regulatory environment. This paper aims at determining the key factors that determine the process of ship disposal. Some of the factors that have been considered are economic variables including changes in freight rates, scrap steel prices, impact of international regulatory regimes and sustainability factors. The sources of secondary data will include a collection of academic materials. The study also analyses the implications of these determinants on disposal choices of shipowners. The analysis provides information that explains the connection between global shipping patterns, international regulatory trends, and sustainability issues. Finally, the study will help to improve the knowledge regarding the role of economic feasibility, regulatory policies, and sustainability factors in shaping the process of ship disposal.

Keywords: Ship Recycling, Ship Disposal, Freight Market, Environmental Sustainability, Maritime Regulations

Introduction

The average lifespan of the commercial vessels is usually designed to last about 25 to 30 years after which they may be considered as technologically redundant or uneconomical. When they collapse to the end of their economic life, the main issue becomes the most effective way of disposing of them. Ship disposal or also known as ship recycling is a process of dismantling maritime ships systematically so as to recover metal, steel, which can be recycled, and at the same time, ensuring that hazardous wastes are safely disposed and that the safety of the workers is not put at risk.

Ship disposal is a complex process per se, which is affected by a wide range of interdependent factors, such as the dynamics of the global freight market, changes in scrap steel prices, maritime regulation changes, environmental factors, and safety measures in recycling plants. India and especially the Alang ship recycling yard stands at a strategic position in the international ship recycling market due to its ability to recycle ships in large quantities and its good pricing formations. The study of the overall determinants that govern the practice of ship disposal is, then, a prerequisite of the design of sustainable recycling strategies.

Literature Review

According to previous literature, the decision-making mechanism, under which the process of ship recycling is organized, is conditioned by the complex interaction of economic aspects, international maritime regulatory regulations, the sustainability of the environment, and socio-cultural factors. Açıık (2017) suggests that these factors determine the point in time when the ships are recycled and the locations where the recycling takes place, along with the techniques used in the recycling process. It is interesting to point out that developing countries in South Asia, like India, Bangladesh, and Pakistan, have become significant

locations in ship recycling, mainly because of the low labor costs, high scrap steel requirements, and lenient regulations in these countries.

Over the last twenty years, scholarly research has continued to focus on further understanding the economic factors which affect the decisions on the disposal of ships, the consequences on the environment and society, and the structures which guide the process. This paper explores these issues in depth in order to gain a detailed understanding of what affects the disposal of ships, especially in relation to emerging economies. Another decisive economic factor is scrap steel, which is the most substantial part of a ship's recyclable value. Merikas et al. (2015) pointed out that the ship-demolition business is closely connected with the steel sector in the world, as the recycling of ship steel is a significant source of global steel (around 1.5 percent). When the price of steel rises, recycling yards can offer high purchase prices for decommissioned vessels, thus encouraging shipowners to dispose of their vessels for recycling. Karlis and Polemis (2016) went on to elaborate on the fact that the demolition market can be described as a financial flow system, where the financial transactions between shipowners, brokers, and recycling yards determine the market equilibrium. The scrap steel prices charged by the recycling yards depend on the international steel prices, currency exchange rates, and freight costs. An analysis of the ship demolition market by Gerostergiou provides an overall macroeconomic view of the ship demolition market by closely examining the supply and demand factors of the ship breaking market. Thus, it can be concluded from the literature that the ship recycling industry plays a vital role in maintaining the balance of the shipping market by eliminating excess capacity in the market during a period of economic downturn. During a period of low trade activities and low freight requirements, shipowners often opt to sell their old ships to recycling yards to avoid incurring losses. Studies have also indicated that more than 70-80% of ship recycling activities occur in South Asia, especially in India, Bangladesh, and Pakistan. Other countries that participate in ship recycling activities, though to a lesser degree, are China and Turkey. Abdullah et al. (2023), in their study, performed a statistical analysis of the global ship recycling industry, with a focus on the supremacy of ship recycling in South Asian countries. The study also explains that the countries in the region have developed into significant ship recycling centers because of low labor costs, high domestic steel demand, and favorable coastal locations for ship recycling activities. Shipbreaking yards located in tidal beaches allow for the grounding of ships, thus avoiding expensive dry-dock facilities.

Environmental issues represent one of the most important challenges associated with ship recycling activities. In particular, vessels built before the 1980s may include hazardous materials such as asbestos, heavy metals, PCBs, and poisonous paint, which may cause environmental pollution of a very severe nature if not properly addressed. Carvalho et al.'s (2009) study aimed at exploring environmental issues in ship dismantling activities and concluded that improper ship recycling practices may cause the discharge of hazardous materials into the ecosystem. Such materials may enter into soil, water and air, which cause long-term environmental pollution and create health risks to local communities. These observations can be supported by empirical studies in ship-recycling areas. As an example, in an investigation on air pollution in Chittagong, Bangladesh, high levels of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and other dangerous pollutants were found close to ship-recycling plants. These pollutants are well known for their severe health risks for both employees and local communities.

One of the themes that can be seen as salient in the literature is the safety and health of the people working in recycling yards. The shipbreaking trade is commonly considered to be one of the most dangerous jobs in the industry, and it is not only because of the existence of hazardous materials and heavy machinery, but also because of the physically demanding nature of the work. Empirical findings show that employees at shipbreaking yards face a lot of risks including explosions, fires, falls off the high platforms, and exposure to dangerous

chemicals that often result in accidents that can be linked to ineffective protective gear, lack of proper training, and poor supervision.

Regulations at the international level are of vital importance for shaping practices in ship recycling. Various international conventions and domestic regulations have been framed to deal with environmental and safety concerns associated with ship recycling practices. The Hong Kong International Convention for Safe and Environmentally Sound Recycling of Ships, 2009, is of paramount importance as it is ratified by the International Maritime Organization (IMO) for framing regulations for ship recycling facilities and for safe disposal of hazardous materials on vessels. In this regard, it is important for vessels to maintain an Inventory of Hazardous Materials (IHM), and ship recycling facilities have to follow certain regulations during ship dismantling activities.

Another important regulatory framework is the Basel Convention, which regulates the movement of hazardous wastes, including dismantled vessels. In addition, the European Union has its Ship Recycling Regulation, which prohibits European-flagged vessels from being recycled at non-approved facilities. However, numerous research works have pointed out challenges in enforcing these regulations. In this regard, Boviatis et al (2019). note that the current regime faces challenges of inconsistent enforcement and institutional weakness, which allows ship owners to circumvent regulations by reflagging vessels or using intermediaries for scrapping. In another study, Ali and Pearce (2020) assessed the effectiveness of the Hong Kong Convention in recycling countries in South Asia and observed that for effective compliance, considerable investments are required in infrastructure, training, and waste management facilities.

However, in recent times, more attention has been paid to ship recycling, and this is in relation to sustainability and a circular economy. Sustainability and a circular economy are concepts centered on responsible use of resources, reuse of resources, and reduction of waste. Recycling a ship is in full compliance with this concept because about 95% of a ship's resources are recyclable. The steel from recycled ships is used in construction.

Ahasan et al (2021). investigated the significance of the application of circular economy practices in the field of ship demolition. The results indicate that the introduction of state-of-the-art technology, environmental regulations, and sustainable management practices can greatly enhance the efficiency of ship recycling activities. Another study conducted by Rahman et al (2017). focused on the consequences of the COVID-19 pandemic on ship recycling from a circular economy point of view. The results indicate that approximately 300 million gross tons of ships are likely to reach the end of their service life in the next five years, thus emphasizing the need to develop sustainable ship recycling facilities. Therefore, from the results of the studies, it is evident that sustainable ship recycling activities require global collaboration, technology, and effective regulations. The importance of the ship recycling industry is quite significant to developing nations, especially with regards to economic growth while at the same time creating issues such as the working environment and fairness. There have been various studies indicating the importance of the recycling industry to the steel sector of a country, with India being a clear example of a country whose demand for raw materials is met by the scrap steel from recycling ships.

However, notwithstanding thirty years of literature, there are still enormous gaps in the literature. The major part of the currently available literature is devoted to the environmental and safety issues.

Objectives

- To study economic aspects that influence ship disposal decisions such as freight market patterns and scrap steel prices.

- To understand how international laws affect ship recycling practices and to examine sustainability concerns and environmental risks associated with ship disassembly.

Research Methodology

This study adopts an exploratory research design supported by secondary data sources.

Secondary Data: Academic papers, industry reports, and policy documents related to ship recycling and maritime regulations are reviewed.

Analysis - Key Factors Affecting Ship Disposal in India -

Economic Factors: The economic variables such as freight rates, prices of scrap steel, age of vessels, and maintenance expenses are extremely important in the decision-making process of ship owners with respect to ship scrapping. In an environment with reduced freight earnings, old ships are less profitable and are thus scrapped. On the contrary, with an increase in freight rates, the ship scrapping process is delayed, and ships remain economically viable.

Regulatory and Legal Factors: International regulations, which include all safety and environmental regulations, govern the process of recycling through the imposition of compliance obligations on shipowners and recycling facilities. Moreover, national regulations in India govern the disposal of hazardous waste, provide for the safety of workers, and promote environmental protection, thus influencing the operational aspects of ship disposal.

Environmental and Sustainability Factors: In this regard, ship dismantling entails the management of hazardous materials such as asbestos, metals, and toxic oils. It is important to ensure that environmentally friendly practices, waste management, and safety measures are implemented for effective sustainability of ship recycling activities. Furthermore, environmental issues affect public opinion and environmental regulations of the industry.

Discussion

Economic factors affecting ship disposal decisions freight Market Influence ; Research shows:

Freight market performance is a vital economic indicator, which affects the decision of shipowners to recycle a vessel. An increase in freight rates increases earnings from vessel operations, even for older vessels with increased maintenance costs. Thus, owners tend to keep them afloat. However, a decline in freight rates reduces earnings, making older vessels less economical due to increased fuel, maintenance, and environmental protection costs. This leads to a situation where owners opt to recycle vessels to take advantage of the value of the steel. The inverse relationship between freight rates and recycling has been well documented with numerous studies.

- Increase in freight rates → Decrease in ship scrapping
- Decrease in freight rates → Increase in ship scrapping

The process of ship disposal in India is affected by various market forces, regulatory environment, and sustainable practices. Economic incentives are the first factor that influences the disposal of ships in India, but the growing international attention towards environmental regulations is changing the face of the industry. The relationship between freight cycles and scrap prices determines the timing of disposal, and international agreements are pushing for safer and eco-friendly practices in ship recycling in India. These aspects highlight the need for support and developments in the ship recycling industry in India.

Baltic Dry Index (BDI) Relation: One of the major indicators of the strength of the freight market is the Baltic Dry Index (BDI), which measures the cost of transporting dry bulk goods

such as coal, iron ore, and grain between major routes. It is also generally considered that the Baltic Dry Index (BDI) is a good measure of the strength of the global freight market since it is calculated based on real market data as opposed to speculation. The changes in the level of BDI are often indicative of the changes in ship recycling. A sharp fall in BDI levels implies a weak freight market with reduced earnings for ship owners, which leads to increased recycling. On the other hand, a BDI level above 2000 points implies a strong market with increased earnings for ship owners. This is because a BDI level below 1000 points implies that the earnings from freight will not be able to support the cost of operation for old ships.

- When BDI falls below 1000 → Ship recycling volume rises significantly
- When BDI exceeds 2000 → Owners continue operating old vessels

Example:

Year	Avg BDI	Ships Recycled
2016 (Low freight)	673	High scrapping surge
2021 (High freight)	2943	Reduced scrapping

History has proven that freight market trends have an effect on ship recycling. In 2016, the Baltic Dry Index averaged 673 points, one of the lowest levels in its history. The low demand for freight led to an environment in which older ships were not worth operating, and thus more of them were recycled, especially in India, Bangladesh, and Pakistan. However, in 2021, the market was revived, and the Baltic Dry Index averaged 2,943 points. The demand for freight was high, and this led to an increase in profits, thus ensuring that older ships were still worth operating and not being recycled.

Scrap Steel Price Impact: Scrap steel prices are vital in the ship recycling industry, impacting shipowners' decisions to dispose of their aging ships significantly. The residual value of a ship is mainly derived from the steel that can be recovered from the vessel, with a study showing that the price of scrap steel contributes approximately 70-75% to the overall value of a ship that is to be recycled. This is because a ship is predominantly made up of steel, with changes in global or domestic prices of scrap steel impacting the amount that shipyards will pay for a ship to be disposed of. With an increase in the price of scrap steel, shipyards will be more profitable, thus offering more attractive prices to shipowners, thereby increasing the rate at which ships are disposed of.

Indicative Scrap Price Trends-

Year	Avg Scrap Price (\$/LDT)	Impact
2016	250–300	High scrapping volume
2020	350–400	Moderate scrapping
2022	550–650	Record recycling activity
2024	480–520	Stable inflow

Scrap steel prices have a historical trend, reflecting the impact of the steel industry on shipbreaking activities. In 2016, scrap steel was quoted at USD 250-300 per long ton (LDT), but the ship recycling operations had been strong in the middle of a slow freight market with

plenty of vessels in the market since most of them were retiring old vessels because of increasing costs of operation. The 2020 prices were USD 350400 per LDT which favours the medium level of scrap activity despite the tensions in the freight and steel industries caused by the COVID-19 outbreaks. In 2022, prices went as high as USD 550- 650 per LDT, which is one of the highest in the industry and an indicator of a healthy freight market, supply chain disruptions and increasing raw material costs to produce steel. As a result, the competitive bids on older ships augmented the ship recycling operations at Alang (India), Chittagong (Bangladesh), and Gadani (Pakistan). In 2024, USD 480–520 per LDT had become stable, a price range that was favoring healthy ship recycling, although at a smaller level than in 2022.

Exchange Rate Impact: Exchange rate fluctuations have a significant impact on the international ship recycling industry, particularly in India, Bangladesh, and Pakistan. Ship sales in the recycling industry are normally negotiated in USD, as most international sea trade is done in this currency. However, operational costs such as labor, transportation, and electricity are usually paid in local currencies such as INR in India. As a result, fluctuations in exchange rates have an impact on the operational costs of the industry, whereby if the local currency drops in comparison to the USD, the income in USD, when converted to the local currency, increases while operational costs remain the same, resulting in higher offers for ships that are to be recycled. The dynamics in exchange rates play a crucial role in determining how competitive a nation is in terms of ship recycling. All three nations, namely India, Bangladesh, and Pakistan, are in competition with each other in terms of acquiring vessels for recycling. Any decline in the Indian Rupee in comparison with other currencies, such as the Bangladeshi Taka and Pakistani Rupee, would enable Indian yards to acquire vessels at a higher price while keeping costs low. In other words, exchange rates are one of the important economic factors in the disposal of vessels. The recycling countries have a currency depreciation that increases the profitability of the vessel dismantling activities thus motivating the wave of subsequent acquisitions. Therefore, the exchange rate dynamics, especially between the Indian rupee and the United States dollar, are highly essential in regulating the disposal of the global fleet vessels.

International Laws Affecting Ship Recycling: Tough global laws have also increased the level of environmental and safety standards whereby the recycling process of the ships is not only safe but also sustainable. This has resulted in a marginal decrease in the amount of ships being recycled due to increased compliance costs. At Alang, India, in FY2024, approximately 125 ships were recycled, compared to 131 in FY2023, a reduction of ~4.5%. The reduction is due to increased compliance costs and favorable freight markets, making it more economical to operate rather than recycle the vessels.

Structural Transformation of Ship Recycling Industry: Freight market performance is a vital economic indicator, which affects the decision of shipowners to recycle a vessel. An increase in freight rates increases earnings from vessel operations, even for older vessels with increased maintenance costs. Thus, owners tend to keep them afloat. However, a decline in freight rates reduces earnings, making older vessels less economical due to increased fuel, maintenance, and environmental protection costs. This leads to a situation where owners opt to recycle vessels to take advantage of the value of the steel. The inverse relationship between freight rates and recycling has been well documented with numerous studies.

Increase in freight rates → Decrease in ship scrapping

Decrease in freight rates → Increase in ship scrapping

Dimension	Pre-Regulation Scenario	Post-International Regulation Scenario
Environmental safety	Minimal controls	Mandatory waste management systems
Worker protection	Informal safety practices	PPE, training, regulated dismantling

International regulatory pressure has shifted India's industry towards:

Prior to these regulations, shipbreaking yards lacked environmental safety, with no effective waste management and minimal control of pollutants. The safety of workers was also not well addressed, with no safety equipment, training, and no standard operating procedure. The standard procedure for shipbreaking was simply beaching, where a ship would be navigated ashore for dismantling with no regard for safety and infrastructure. However, after the adoption of international standards, shipbreaking yards have improved in terms of waste management for hazardous materials such as asbestos, oil residue, and metals; better protection of workers through personal protective equipment, training, and standard procedure; and better facilities for shipbreaking yards to meet international standards, resulting in HKC-compliant green recycling yards. Growth in HKC-Compliant Ship Recycling Yards in India

Year	HKC Compliant yards (approx.)
2010	5
2015	35
2018	70
2021	94
2023	110
2025	110+ operational compliant Yards

The tables that accompany the article show how the ship recycling industry in India evolved and how it was shifted to conform to international environmental and safety requirements, that is, the Hong Kong Convention (HKC).

There has been a rapid increase in HKC compliant yards with the figures increasing to over 110 in the year 2025 compared to five in the year 2010. This is a trend that highlights a large-scale investment in the modernization of facilities to comply with the green recycling demands of nations across the globe.

Ship Recycling Volume vs Regulatory Stringency

Year	Recycling Volume (MnGT)	Regulatory phase
2010	3.5	Pre HKC adoption
2015	4.5	Voluntary compliance emerging
2018	5	India accedes to HKC
2021	5.2	Stricter environmental norms

2024	3.8	Compliance cost pressure
2025	4 (est.)	HKC enters into force

Although the recycling volume was at its maximum around 2021, with a figure of 5.2 MnGT, there is a visible 'compliance cost pressure' observed in 2024, where the volume is at 3.8 MnGT. The data show that with an increase in regulatory stringency and official accession of India to the Hong Kong Convention (HKC), the industry was subject to an adjustment period, where operational costs had a restraining influence on the costs. The year 2025 is another critical year in which the HKC would become operative. In spite of these regulatory pressures, these production volumes will stabilize at the 4 million gross tonnes with the existing infrastructure of over 110 yards making India a global leader in sustainable ship breaking.

Environmental & Safety Compliance Impact

Indicator	Pre 2015	Post 2025 HKC
Hazardous Material Inventory	Rare	Mandatory
Worker Safety Standards	Low	High
Waste Management Protocols	Weak	Strict Compliance
Authorized Recycling Plans	Optional	Required

The table shows a sharp change in the operational standards of the ship recycling business and compares the situation in the pre-2015 wild west with the current highly regulated environment introduced following the Hong Kong Convention of 2025 (HKC).

Hazard material management: In the past, it was not common to monitor the toxins, it is now mandatory to have an Inventory of Hazardous Materials (IHM) to protect work practices relating to such substances as asbestos or lead. **Operational accountability:** The industry has shifted to an optional plan of recycling that is accompanied with poor waste practices to a model where each vessel has an Authorized Recycling Plan to ensure there is a systemic monitoring of operations within the industry and the enforcement of environmental friendly practices. **Human factor:** There has been a significant improvement in the safety standards of the workers; the safety levels that were historically loose have been replaced with a strong safety regulation that ensures that accidents and the long-term effects of the health of the worker are reduced. On the whole, the statistics show that the industry has evolved into a controlled process where the safety and environmental concerns are not only mandatory but also compulsory.

Reactive Nature of Current Ship Disposal Strategies

Current trends in the industry have been characterized by a rather reactive trend, focusing more on the immediate market dynamics, than having a long term strategic plan.

The decision making procedure adopted by ship owners as regards to disposal of vessels is influenced by the following factors:

- Immediate freight market conditions
- Variations in the price of scrap

The absence of prediction models for decision-making is limiting the efficiency of the industry. The research study reveals that proactive decision-making is at the evolutionary stage in the industry.

Managerial Implication

1. **Strategic Decision-Making Using Market Indicators:** Managers ought to assume the position of data-driven structures through following the movement of freight rates and scrap steel prices as well as fluctuations of exchange rates. It is implemented in dashboards, predictive analytics and decision triggers.
2. **Cost-Benefit Optimization:** Do a financial analysis between recycling and continued operation. It will make sure that assets are utilized best.
3. **Worker Safety and HR Development :** Suggest PPE, health and safety training and facilities. Impact: Decreases accidents and increases productivity.
4. **Sustainable and Green Practices:** Implement green technologies and circle economy behaviors. Impact: Improves competitiveness and sustainability.
5. **Digital Transformation:** Adopt ERPs, Artificial Intelligence, and online platforms. Impact: Enhances efficiency and transparency.

Conclusion

The current investigation surmises that the disposition of ship in India is determined by a nebulous of connected reasons such as the state of the economic marketplace, international regulations, and the problem of environmental sustainability. Freight markets crashes and scrap-steel price hikes usually hasten ship-recycling, and strong freight markets usually delay the decision to dispose. Also, the growing regulatory pressure and the increasing concern of environmental risks are driving the development of recycling practices. The main changes required to maintain India as a global leader in ship recycling include strengthening regulatory enforcement, investment in green recycling technologies and improving the worker safety rates. The long-term sustainability of the ship-disposal sector in India will be guaranteed through a balanced approach between economic effectiveness and environmental care.

Suggestions

Adoption of Forecasting Models: It is advisable that time-series analysis and forecasting models, like ARIMA, be used in studying the trend of ship-recycling in the future. This recommendation is especially timely in the light of projections suggesting that there will be about 300,000 gross tons of vessels that will have gone to obsolescence in the near future. The prediction techniques will be crucial in providing useful knowledge on the future trends of ship recycling.

Enhanced Primary Data Collection: In order to enhance the empirical basis of the study, primary data collection techniques, such as surveys, structured interviews, and observations, should be also included in the future studies. These methods can be used to generate a holistic representation of the shipping business, as they involve interaction of the stakeholders. In addition, they allow obtaining primary data on the behavioral facets of the decision-making processes, which cannot be obtained by using secondary data alone, which increases the validity and reliability of the study.

Integration of Cost-Benefit Analysis for Regulations: The cost benefit analysis of regulatory frameworks like the Hong Kong Convention is critical. The present analysis should be accompanied by quantitative evaluation of the expenses of regulatory compliance, which may include the cost of infrastructure expansion, acquisition of protective equipment, and installation of waste-management systems. They have to be balanced with the benefits that the lowered environmental degradation, the enhanced safety of the workers, and the augmented global credibility will have. The result of this type of analysis would help policy

makers to attain a subtle balance between sustainability requirements and the economic costs that the players in the industry bear.

Investment in Worker Safety and Skill Development: Since the recycling of ships is a risky process, it is necessary to invest in safety and training systems continuously. This involves the supply of protective gears, compulsory safety training, and health care centers. Improved working conditions reduce the number of accidents as well as increasing productivity levels and enabling the sustainability of the industry. Government intervention and regulation is therefore, inevitable towards achieving the above goals.

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Comparative Analysis of Container Imbalance in Indian Ports

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Abstract

The study measures container imbalance at chosen Indian ports like Mundra, Kandla, Cochin & Tuticorin through the Container Availability Index (CAx) inspection method. The research aims to examine CAx trends over a defined period, identify key factors contributing to container surplus or shortage, and evaluate the effectiveness of existing container management strategies. The major Indian ports studied through comparative analysis show multiple container availability discrepancies between different regions. The primary causes of imbalance are trade asymmetry and infrastructure constraints together with operational inefficiencies and shipping line allocation patterns. The study presents practical and policy-level strategies which include digital forecasting systems and container pooling mechanisms together with improved hinterland connectivity and coordinated repositioning frameworks. The study results help organizations achieve better operational performance while they work to establish environmentally friendly container management methods in India's maritime industry.

Keywords: Container Availability Index (CAx), Container Imbalance, Port Performance Analysis, Container Management Strategies, Indian Ports, Supply Chain Efficiency

Introduction

The Indian coastline which extends beyond 11098 kilometers shows its importance to the world maritime economy because the country conducts 95 percent of its international trade through its seaports. The West Coast ports of India including Jawaharlal Nehru Port Trust, Mundra Port, Mumbai, Mormugao, New Mangalore, and Cochin Port, benefit from their natural harbors which offer deeper waters and their stronger industrial support and their superior links to worldwide trade routes that connect Europe with the Middle East and Africa and the Americas. The East Coast ports of Kolkata-Haldia and Paradip and Visakhapatnam and Chennai Port and Ennore (Kamarajar) and V.O. Chidambaranar Port serves as trade gateways to Southeast Asia and East Asia while their exports include textiles and seafood and electronics and minerals and their imports include coal and fertilizers. The container traffic expansion during the early 2000s period succeeded in bringing major changes to India's logistics industry while structural coastal differences maintain their influence on how ports operate and how trade activities progress between different regions.

The growth process encounters difficulties because container imbalance creates an uneven situation where import and export containers distribute themselves unequally, which results in export-heavy ports experiencing container shortages, while import-dominant ports encounter empty container surpluses. The problem escalates because trade imbalance exists together with insufficient infrastructure and worldwide disruptions and dependence on international shipping companies. The West Coast obtains most of its container throughput because it maintains direct connections to mainline shipping routes, whereas the East Coast operates at lower capacity and depends on transshipment facilities located in Singapore and Colombo. The recent CAx developments show that East Coast ports like Chennai experience both irregularities and temporary shortages, while Mundra and JNPT ports on the West Coast show more consistent operations despite their seasonal traffic peaks. The contrasting results between parties demonstrate that additional research must happen.

Literature Review

A study of Container availability (2024) has assumed the role of a key indicator to learn about the global container movement and logistics efficiency. As stated by the container logistics platform Container xChange (2024), Container Availability Index (CAx) was created as a tool to track the patterns of container supply and assess the availability of equipment at ports in real-time. A CAx value of more than 0.50 is usually a sign of excess inbound containers at a place, whereas a CAx of less than 0.50 is a sign of a shortage. With time this index has become a useful tool to logistics companies and researchers in understanding the pattern of flow of containers and aiding in designing operations at the port level. Barriers to Port Logistics in the Industry 4.0 Era (2021) The research undertakes an in-depth analysis of the major hurdles to port logistics in emerging markets, such as India, through a workshop and Total Interpretive Structural Modeling. A total of eighteen hurdles were considered in the study, and through the MICMAC analysis, the driving and dependence power were classified. Non-supportive policies, infrastructure, and R&D are seen as major challenges in port logistics, which affect the efficient movement and balancing of containers. These hurdles could be addressed to reduce costs and improve the efficiency of operations through data-driven decisions.

Objectives

1. To examine the patterns and variations in the Container Availability Index (CAx) across selected Indian ports over a specific time period.
2. To determine the major factors responsible for the occurrence of container surpluses or shortages at ports.
3. To assess the container management practices implemented by ports and shipping stakeholders and analyse their effectiveness in addressing container imbalance.

Scope of the study

This research focuses on Indian ports like Mundra, Kandla, Cochin & Tuticorin, which play a vital role in the country's maritime logistics system, especially in relation to containerized cargo movement. The study examines patterns in import and export container flows to understand how container availability changes over time. It also evaluates the efficiency of container utilization and the turnaround time involved in port operations. The analysis makes use of Container Availability Index (CAx) data to interpret trends in container supply and demand. Additionally, the study reviews strategies adopted by ports and shipping lines to manage container imbalances. Both international trade dynamics and domestic operational factors that influence container movement at Indian ports are also considered within the scope of this research.

Research Methodology

Research Design:

The research design for this thesis is a Exploratory approach, focusing on analysing container imbalance patterns across selected West and South Coast ports using secondary data. It employs a comparative framework to detail CAx trends,

Sources of Data

Secondary Data Collection Container xChange CAx Index: The CAx data used in this study was obtained from the platform Container xChange, which provides global container availability information. The index is generated using pickup and drop-off transaction data collected from container leasing marketplaces and shipping carrier networks, allowing researchers to track container supply patterns across ports.

Shipping Lines Data: Additional port-related information was gathered from shipping companies operating at major ports. These sources provide insights into container movement, vessel operations, and equipment allocation.

Industry Reports and Publications: Relevant information was also reviewed from academic research papers, logistics and maritime journals, and international trade publications. These sources provide background knowledge on container imbalance, port operations, and broader global trade dynamics.

Sample Design

Time Frame for this study, CAx data was gathered for a continuous period of one year, covering January 2024 to December 2024. This time range was selected to observe changes in container availability across different months and seasons and to identify patterns in container surplus and shortage during the year.

Analytical Tools and Techniques

The research applies various analytical methods to examine container availability and identify the level of imbalance at selected West and South Coast ports using the Container Availability Index (CAx). The analysis is primarily based on data interpretation, focusing on weekly variations in container movement and availability. By examining these patterns, the study aims to understand how container flows fluctuate over time and how these fluctuations affect port operations and overall logistics efficiency.

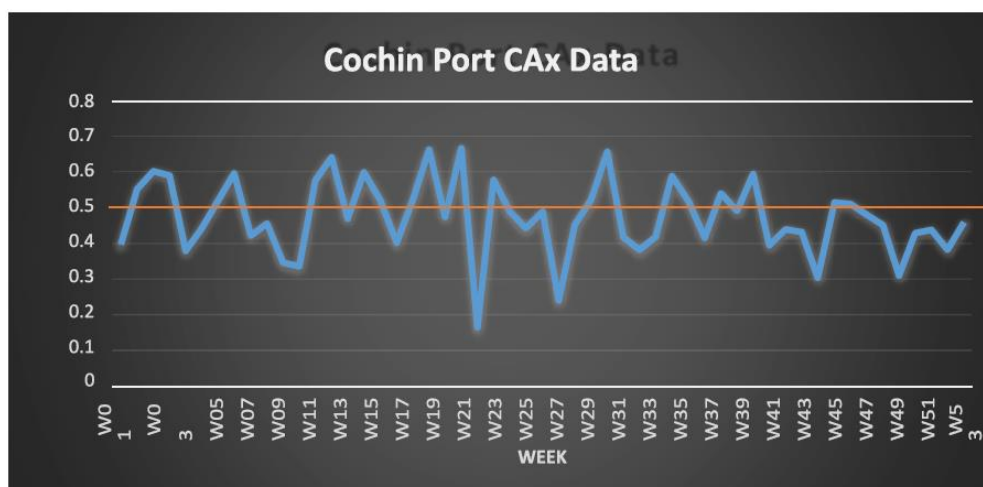
Analysis of the CAx Index :

One important indicator that shows the weekly balance of container inflows and outflows at a port is the Container Availability Index (CAx), which was created by Container xChange.

The CAx value is interpreted as follows and falls between 0 and 1:

- $CAx < 0.5$: This means that there are more containers being picked up than being dropped off, which indicates a container shortage.
- $CAx > 0.5$: This means that there are more containers being dropped off than being picked up, indicating a surplus.
- $CAx = 0.5$: Indicates that the container flow is balanced.

Trend Analysis: CA_x Data Interpretation For Cochin Port (JAN 2024 – DEC 2024)



Analysis: 2024 year marked by volatility and periodic shortages, particularly in Q1 and Q4.

Interpretation:

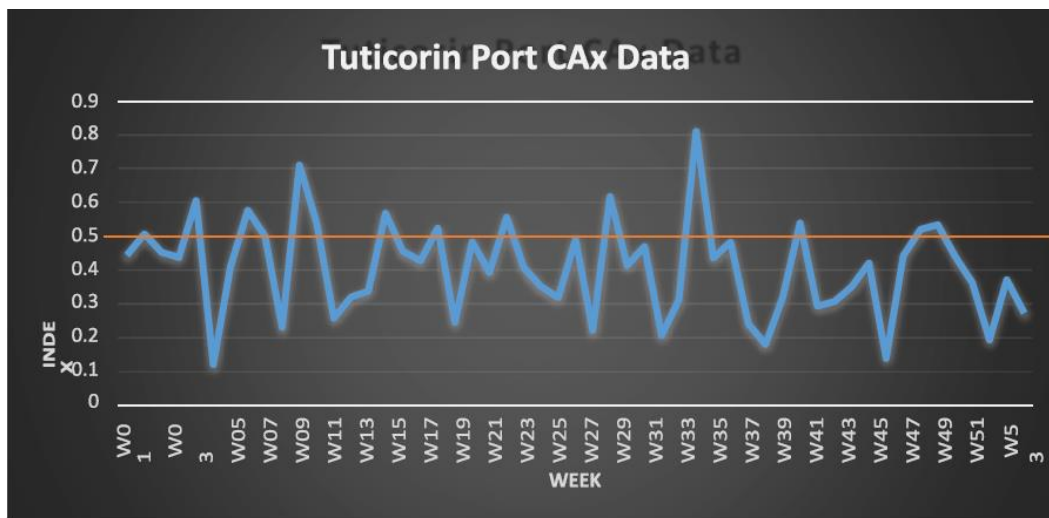
2024 for exporters will bring higher prices and delayed bookings. In 2024 Shipping Lines will face blank sailings and inefficient repositioning. Port Authorities will encounter significant needs for better digital visibility and improved coordination between ICDs and CFSs. Seasonal Trends

Q1/2024 will have consistent shortages (New Year demand).

Q2 will experience partial recovery from global supply chain disruptions.

Q3 should see substantial surpluses of equipment

Trend Analysis: Ca_x Data Interpretation For Tuticorin Port (JAN 2024 – DEC 2024)



Year 2024 Summary

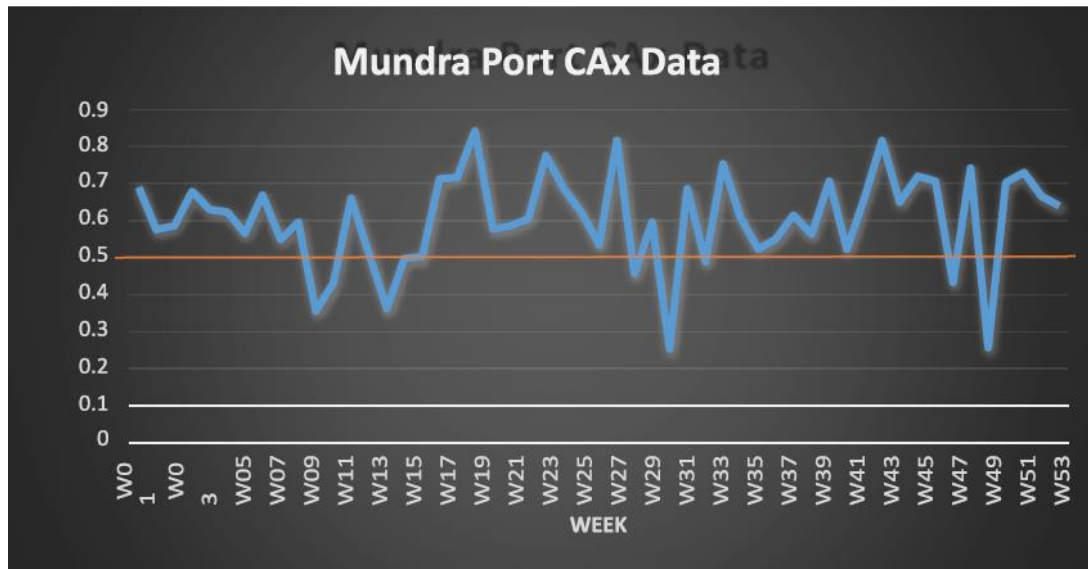
Total weeks	:	53
Surplus Weeks	:	14
Shortage Weeks	:	39
Zero Weeks	:	0
Peak Cax	:	81.1
Lowest Cax	:	~12.0

Interpretation: The year 2024 experienced even more significant shortage pressures, with multiple weeks recording critically low levels (<20 CAX). Export operations faced severe disruptions.

Interpretation:

- Exporters will be facing ongoing issues of not being able to secure empty containers, which has resulted in delays of shipments and higher repositioning costs.
- Shipping lines will experience the need for better positioning strategies; container pooling; and collaboration to meet export market needs.
- Port authorities will need to invest in developing ICDs/CFSs capacity and improve coordination with shipping lines.

Trend Analysis: Cax Data Interpretation For Mundra Port (JAN 2024 – DEC 2024)



Year 2024 Summary

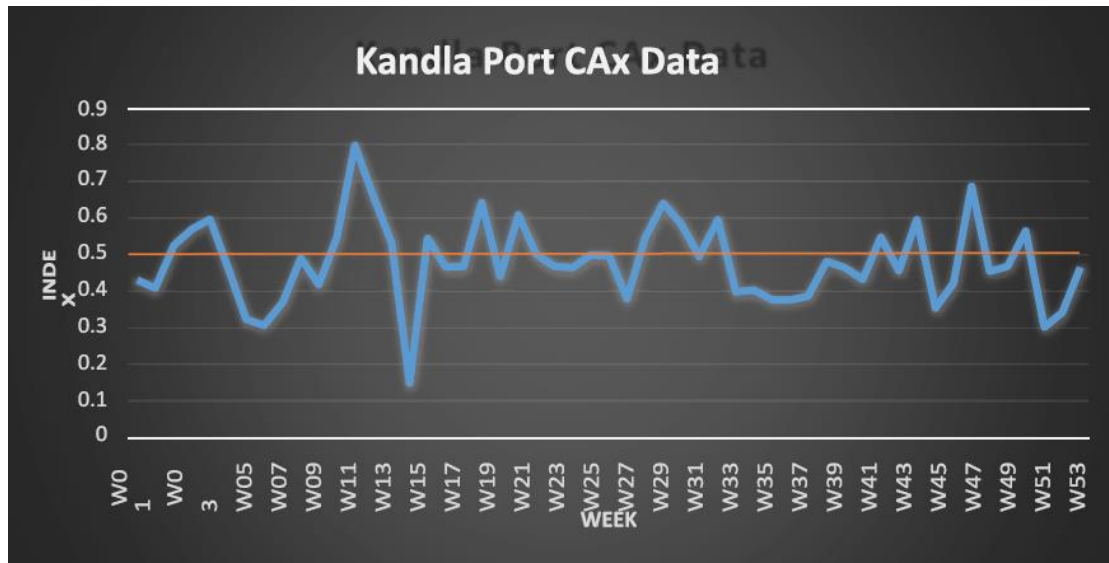
Total Weeks	: 53
Surplus Weeks	: 44
Shortage Weeks	: 9
Zero Weeks	: 0
Peak	CAX:
Approximately	84.3
Lowest	CAX:
Approximately	25.4

Interpretation: The year 2024 remains predominantly surplus but exhibits increased volatility along with several critical shortage weeks (outliers), indicating potential episodic export pressures or operational challenges.

Interpretation:

- Exporters will have access to empty containers with relative ease during most weeks; Repositioning costs will be lower.
- Shipping Lines may need to improve the utilization of empty container storage capacity; and there will be more inbound pressure on yard space.
- Port authorities need to manage yard space and record equipment turnover to avoid congestion caused by long-term oversupplies.

Trend Analysis: Cax Data Interpretation For Kandla Port (JAN 2024 – DEC 2024)



Interpretation:

- Exporters will need to reserve empty containers in advance during times of intermittent shortages.
- Shipping Lines will need to have effective equipment distribution management in advance of weeks of empty container shortages.
- Port authorities will be able to support stabilisation of operations through improving infrastructure- sharing and providing real-time monitoring.

The synthetic CAX profile of Kandla Port indicates that it operates fairly balanced, yet is susceptible to occasional shortage stress. Resilience relies on data-informed repositioning and proactive planning.

Comparative Analysis:

Port	Total Weeks	Surplus Weeks	Shortage Weeks	Zero Weeks	Peak CAX	Lowest CAX
Cochin	53	21	32	0	~66.8	~16.6
Tuticorin	53	14	39	0	~81.1	~12.0
Mundra	53	44	9	0	~84.3	~25.4
Kandla	53	19	33	0	~80.0	~15.0

This is a comparative analysis of the 2024 Container Availability Index (CAX) of Mundra Port, Kandla Port, Cochin Port and V.O. Chidambaranar Port. The findings indicate that the container availability and operational balance of these four ports vary significantly.

Mundra Port has exhibited the most stability among the four ports with 44 weeks (surplus) and 9 weeks (shortage) in terms of container availability. The characteristics of its high CAX (peaks of about 84.3 and troughs of approximately 25.4) demonstrate that even though CAX values for Mundra may fluctuate throughout the year, it predominantly maintains a surplus position.

While Kandla Port and Cochin Port experience moderate levels of operational imbalance, Cochin has 21 weeks (surplus) and 32 weeks (shortage) of container availability, indicating that containers were available at certain points in time; however, there were periods of shortage due to trade flow fluctuations and operational constraints. Kandla exhibited a similar operational imbalance with 19 surplus and 33 shortage weeks, with a slightly lower peak CAx of approximately 80.0.

Conversely, V.O. Chidambaranar Port (Tuticorin) recorded the greatest operational imbalance (14 weeks surplus and 39 weeks shortage). Tuticorin experiences continued shortages of containers. Although it experienced a high peak CAx of approximately 81.1, it also has a low minimum value of approximately 12.0, indicating that there were numerous periods of very severe container shortages. In summary, Mundra Port is the port with the most consistently stable level of container availability.

Discussion

Definite East to West/Regional and Imbalance

- Mundra and Kandla on the east coast are projected to have consistently high CAx Values (> 0.5) indicating a surplus of containers.
- Tuticorin and Cochin should exhibit frequent CAx Values that are below 0.5 meaning they have persistent shortages.
- This indicates that the availability of containers in India is uneven geographically and is affected by the concentration of trade on the west coast.

Significant Relationship Between the Structure of Trade and Imbalance of Container Availability

- Ports that primarily handle imports (industrial inputs such as PET, machinery, petroleum etc.) end up with a large number of empty containers.
- Ports with significant exports or those that mostly have seasonal exports (textiles, agricultural goods, seafood) and have limited inbound containers face shortages.
- It is expected that the study will confirm that the lack of an equal mix of goods for both export and import traffic is the major reason for the imbalance.

Infrastructure and Operational Constraints Contribute to the Imbalance

- The delay of container movement due to poor hinterland connectivity, limited capacity of ICD/CFS, and long dwell times at specific ports results in an imbalance of container availability.
- Ports with deeper drafts will typically have higher train and truck loads and a more frequent vessel service will have a more stable CAx.

Current Management Strategies for Containers Are Partially Successful

- Current management strategies such as repositioning of empty containers, leasing containers and ad-hoc pooling are only temporary solutions to reduce shortages.
- Limited inter-port coordination, predictions of container flows, and lack of a shared inventory of containers also contribute to container imbalances.

Managerial Implication

An Empty Container Coordination Initiative

The Empty Container Coordination Mechanism is to be established by the Ministry of Ports, Shipping & Waterways at the national level. The national framework will oversee the

flow of containers between ports, sharing of data, and repositioning of containers from ports to either hold for emergencies or return back to the ports.

Support for Domestic Transshipment Hubs

Work to make Indian Ports such as Vizhinjam, JNPT and others into domestic transshipment hubs (similar to Africa's hubs and those of Indonesian ports) and to stop depending on transshipment hubs in Colombo and Singapore. This will keep the containers on Indian trade routes and minimize the number of repositioning delays of containers.

Use of Digitalization and Predictive Analytics

Promote AI supported demand forecasting, blockchain tracking, and integrated port community systems. Digital visibility of the containers will allow the stakeholders to forecast the shortage of the containers weeks in advance and plan the movement of the containers effectively.

Regulatory support for Container Sharing

Develop guidelines that allow a carrier to interchange containers with a different carrier while addressing the carrier's legal and business issues.

The sharing of containers from one carrier to another is expected to greatly reduce the number of repositioning of empty containers and the carbon footprint from the repositioning of the empty containers.

Supporting Sustainability Initiatives

Minimizing the unnecessary repositioning of empty containers is an integral part of India's goal of reducing logistics costs and promoting green port initiatives. Therefore, the optimization of the flows of containers will assist in reducing fuel (energy) consumption and resulting emissions.

Conclusion

Container imbalance at select Indian ports has been examined by using the Container Availability Index (CAx) to analyze individual ports. Ports studied include Mundra Port, Kandla Port, Cochin Port and V.O. Chidambaranar Port. Container availability levels at the four ports differ greatly because of factors such as differing trade patterns, operational capacity issues and connections to global shipping networks. Overall, Mundra Port had the most stable containers available for that period with more surplus weeks than the other three ports, therefore demonstrating efficiency in port operations combined with strong connections to international trade lanes. Conversely, the Port of Tuticorin had the greatest number of days with insufficient containers; therefore it would seem that exporting goods and not receiving enough containers from inbound shipments resulted in causing this issue. Container availability levels at both ports of Cochin and Kandla were also somewhat predictable based on their respective cargo flows and other operational conditions that changed periodically throughout the year.

Additionally, this research shows that container imbalance can be caused by a number of different contributors including the difference between imports and exports into/out of individual ports, established infrastructure limitations, different types of ocean carrier vessels on which cargo moves and the need for better coordination of the logistics for putting cargo from various geographic areas to/from the different ports. When containers build up at one port while there is a shortage of containers available at other ports, then the costs associated with repositioning those containers increases, which ultimately results in less efficient supply chain management. Thus, to improve container management between ports will require better coordination between the various ports, shipping lines, and logistics customers. Other considerations may include the use of digital systems to track containers, utilizing more accurate demand forecasts, and improving hinterland connections.

Suggestions

Port Level Container-Pooling Mechanisms

- Form a regional container pool at local ports to let shipping companies share empty containers when they are available.
- This reduces duplicate costs for shipping companies going back and forth and also helps with availability of containers during busy (peak season) times for exports.

Implementing Real-Time CAx-Based Monitoring Systems

- Use CAx or related indices on operational dashboards in ports to manage day-to-day operations of the port.
- Ports will be able to schedule bookings for containers in advance if they are able to see early warning signs of a decline in CAx values.

Increase the Capacity of Inland Container Depots (ICD) & Improve Connectivity to the Inland Area

- Build more ICDs close to collection points for export shipments available in the local region and use them as temporary holding areas for empty containers.
- Make improvements to the rail system from the ports that have a surplus of containers to the ports that have a shortage to facilitate quicker movement of containers between ports.

Speed Up Container Turnaround with Incentives

- Reduce storage fees or give priority in handling to companies returning containers shortly after unloading.
- Doing this will increase the speed of containers moving through the cycle and expand availability.

Export Driven Planning at Ports with a Shortage of Containers

- Work with shipping companies on establishing export schedules that coincide with other exporters so that they can be booked during the busy time of year (ex: textiles, seafood).
- Urge exporters to use advance booking & sign long term contracts for use of containers.

Limitations

This study mainly relies on secondary sources of information such as CAx data reports, port authority statistics, shipping company publications, and trade-related reports. Due to constraints related to time and resources, primary data collection through field surveys or interviews was not undertaken. As a result, the findings are based on available published data and may not capture real-time operational perspectives from port authorities or shipping stakeholders.

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Transformation of Shore Level Maritime Professionals to Logistics Personnel in Modern Shipping Era

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Abstract

The maritime and port logistics sector is experiencing a transformational shift, largely attributed to developments in digitalisation, changing sustainability expectations and increasingly intricate global supply chain networks. The workforce is also suffering from a considerable skills shortage. The primary objective of this research is to assess the present-day situation of shore-level professionals in the maritime industry and to develop a tripartite competency framework (i.e., core, functional and leadership competencies) tailored to the freight forwarding industry. An exploratory and descriptive research design was used and primary data were collected from the 50 freight forwarders using a structured Likert scale questionnaire in Gujarat. Descriptive statistics and one-sample t-tests were employed to analyse the data. Preliminary results reveal strong global agreement on the importance of all three categories of competencies, with the mean score for each category being equal to or greater than 4.1. Core competencies received the highest rank (Mean = 4.22), while functional competencies demonstrated the greatest level of agreement (SD = 0.77). Furthermore, all of the results support the statistically significant importance of these competencies in today's shipping industry, leading to the rejection of the null hypothesis. The findings of the study indicate that maritime organisations need to move from tenure-based approaches to competency-based practices in relation to recruitment and evaluation of their workforce. In addition, the results of the research strongly recommend an industry-wide standardisation of these competencies to develop a future-ready workforce.

Keywords: Competency Framework, Freight Forwarding, Maritime Logistics

Introduction

Maritime and port logistics, which account for more than 80% of worldwide merchandise transportation, are essential elements of global trade and serve as the foundation of international supply chains. Nevertheless, the industry is confronted with progressively increasing challenges influenced by globalization, swift digital advancements, and increasing requirements for sustainability. So, as a part of industry it becomes necessary to improve the operational transformation by the development of highly skilled professionals with well-defined technical, management, and interpersonal competencies as traditional workforce skills are increasingly insufficient in responding to these shifts to maintain the sector's efficiency and competitiveness. (Luís Silva Lopes et. Al 2025)

Maritime Education and Training (MET) institutions and companies must adapt curriculum and workforce development strategies to produce graduates who can manage increasingly complex systems (Mehdi Belabyad et. al 2025). A competency framework is a formally defined model that shows the fluency of an individual person for specific skills, knowledge, and behaviours in a specific role, team, or organization. It is a roadmap of competencies, providing an explicit and shared means of understanding of what success looks like. In the field of organizational behaviour, they help structure recruitment, training, performance management, and succession planning by defining observable competencies and their proficiency levels. (Mehdi Belabyad et. al 2025)

Consequently, this thesis aims to develop a competency framework tailored for a shipping company to identify, develop, and leverage the full spectrum of skills, knowledge, and behaviours essential for organizational excellence to ensure that future professionals are better equipped to navigate the challenges of digitalization, sustainability, and supply chain resilience in an increasingly complex industry. (Luís Silva Lopes et. Al 2025)

Literature Review

According to Lopes et al. (2025), the gap between the academic training and industry needs remains critical, and there is a strong necessity to assess the capabilities of the workforce and the ability to fulfill the requirements in the maritime environment by reevaluating the competency frameworks in the context of the changing environment. To lay the groundwork to this, Chen and Chang (2011) state that defining core and human competencies is critical in the attainment of a sustainable competitive advantage by an organization. Based on this organizational theory, Chouhan and Srivastava (2014), the International Atomic Energy Agency (2016), Jia and Fan (2008), and Pathak and Ravaliya (2022) all promote the idea of involving competency models to facilitate high performance and to efficiently lead the process of strategic human resources, staff development, performance management, and competency-based systematic interviews. To make these models dynamically applicable, Child and Shaw (2023) and Ghanwat (2025) suggest that they should be constantly validated with the help of stakeholder participation and the introduction of AI-based evaluating instruments. Placing this in the context of global supply chains, Skiba and Kara (2022) as well as McKinnon et al. (2017) note that the business model of freight forwarders is currently undergoing rapid change as more of them are becoming less of a service contractor than a multi-stakeholder supply chain coordinator, a change that has uncovered pervasive global skills gaps that need an urgent multi-stakeholder intervention. According to Belabyad et al. (2025), Bhardwaj (2023), and Koh and Yuen (2022), this operational shift is extremely enhanced by digitalization, Industry 4.0, and Maritime Autonomous Surface Ships (MASS), which have an urgent need to learn new maritime skills specific to specialized digital, automation, and cybersecurity. These key industry capabilities are defined into functional and operational ones by Katinienė et al. (2021), Drejeris et al. (2024), and Vettriselvan et al. (2023) as the primary determinant of both the efficiency and competitiveness of the organization every day: customs compliance, IT proficiency, and material flow control. At the same time, Saribanon et al. (2025) and M. Said et al. (2025) prove that strong customer service competencies and such cognitive factors as perceived trust are useful in promoting service quality, risk management, and adoption of freight forwarding as a whole. Lastly, Jakubowski (2020) claims that the effective coordination of all these technical and operation capabilities depends significantly on the dynamic leadership capabilities, in which strategic business orientation, relational building, and active change management are the most crucial attributes that navigate market pressures. Taken altogether, all this literature points to the need to create a comprehensive, empirically proven competency framework that is inclusive of core, functional, and leadership facets to effectively equip the professionals working on shore in a way that makes them ready to work in the modern shipping environment.

Objectives

1. Evaluate the current statistical status of employees (age, qualification, experience, job role) working in shipping industry
2. Formulate a competency framework based on three components aligned with Maritime industry

3. To evaluate the perceived importance of core, functional, and leadership competencies among freight forwarding professionals in the modern shipping industry

Formulation of Hypothesis

- Objective 3rd: To evaluate the perceived importance of core, functional, and leadership competencies among freight forwarding professionals in the modern shipping industry

H₀: There are no importance of core, functional, and leadership competencies among freight forwarding professionals in the modern shipping industry

H₁: There are significant importance of core, functional, and leadership competencies among freight forwarding professionals in the modern shipping industry

Need for the study

A competency framework is crucial for the freight forwarding industry due to rapid and disruptive changes. The sector is experiencing a significant shift driven by **digitalization**, with automation and data analytics becoming central to operations. This creates a skills gap, where traditional roles are evolving and new technical proficiencies are required. Furthermore, global supply chains are growing increasingly **complex and volatile**, demanding advanced problem-solving, risk management, and strategic planning skills that are often underdeveloped. (<https://www.transvirtual.com/us/blog/logistics-skills-gap/>)

There's also increased demand on **sustainability** and complex international trade regulations, requiring a workforce knowledgeable in green logistics and compliance. A standardized competency framework addresses these challenges by clearly defining the skills, knowledge, and behaviors necessary for success. It enables targeted training and development, improves recruitment and retention, standardizes performance evaluation, and aligns employee capabilities with strategic business objectives. Ultimately, it equips freight forwarding companies to build a workforce capable of navigating the industry's dynamic future.

Competency Study

A competency study is a systematic research approach used to identify, define, and validate the specific knowledge, skills, behaviours, and attributes required for better performance in particular roles in an organization. developed by Dr. David McClelland at Harvard University, competency studies include data collection and analysis using scientific methodologies to establish which competencies are actually required for excellent job performance. (<https://workitect.com/research-intuitive-approaches/>)

Competency studies involve systematic data collection through methods such as interviews, questionnaires etc. McClelland gave the term "Iceberg Model" which describes competencies as having visible elements (knowledge and skills) above the surface, while deeper characteristics like self-image, traits, and motives remain hidden but are crucial for predicting performance. (<https://repo.uum.edu.my/id/eprint/15943/1/P14.pdf>)

Competency Framework

A competency framework is a structured model that defines the specific skills, knowledge, behaviours, and attitudes required for employees to perform effectively in their roles within an organization. Unlike simple job descriptions, a competency framework serves as a comprehensive blueprint that connects individual performance to organizational success by providing measurable standards and clear expectations. (<https://www.techtarget.com/searchhrsoftware/definition/competency-framework>)

The framework typically includes three main components: core competencies that apply to all employees regardless of role and essential skills, knowledge is involved here which reflects organizational values; functional competencies (i.e. technical expertise, industry specific skills) that are role-specific and relate to particular positions or departments; and leadership competencies (i.e. strategic thinking, problem solving) that identify qualities necessary for management roles. Some frameworks also include meta competencies - beneficial qualities like adaptability and flexibility that are relevant across work environments (<https://devskiller.com/blog/competency-framework-development/>)

Competency frameworks serve multiple strategic purposes including recruitment and selection, performance management, training and development, career planning, and succession planning. Research indicates that organizations with clearly defined competency frameworks are 50% more likely to achieve their strategic objectives (<https://devskiller.com/blog/competency-framework-development/>)



Research Methodology

Research Design:

It is a Descriptive and Exploratory research design. The use of a structured questionnaire (with likert scale responses) aligns with how competency studies are systematically assessed among targeted populations in similar research. This design help enables the evaluation of employee competencies and the identification of skill gaps across multiple competency dimensions

Sources of Data:

PRIMARY SOURCE: When a researcher gathers first-hand information for a particular study or purpose, it is referred to as primary data. It is unique and hasn't been collected or processed by anybody else before.

I collected the primary data by collecting data through conducting a survey and getting questionnaires of google form filled by appropriate individuals.

SECONDARY SOURCE: Information that has already been gathered, analysed, and released by other people, groups, or institutions for objectives unrelated to the researcher's current investigation is referred to as secondary data.

For the secondary data I reviewed various journals, publications and government authorized documents

Target Population:

- **Element:** Shore level maritime professionals (with a focus on freight forwarding personnel) working in the shipping and logistics industry.
- **Sampling unit:** Individual professionals working in freight forwarding companies shipping lines logistics service providers and port related agencies.
- **Extent:** Freight forwarding companies especially in Gujarat region and companies which are into logistics sector
- **Time:** Data collected from Oct 2025 to 2026

Sampling Technique

Convenience Sampling: as a researcher selecting freight forwarding individuals from Gujrat region is most convenient to me.

Purposive Sampling: for my research paper individuals working in freight forwarding industry are best fit

Snowball Sampling: as a student it becomes hard to individually contact freight forwarding professionals. So, to fulfil that gap I'll also use snowball sampling and tell few freight forwarders to refer other and send them google survey form

Sample Size

50-60 respondents

Expected Outcome

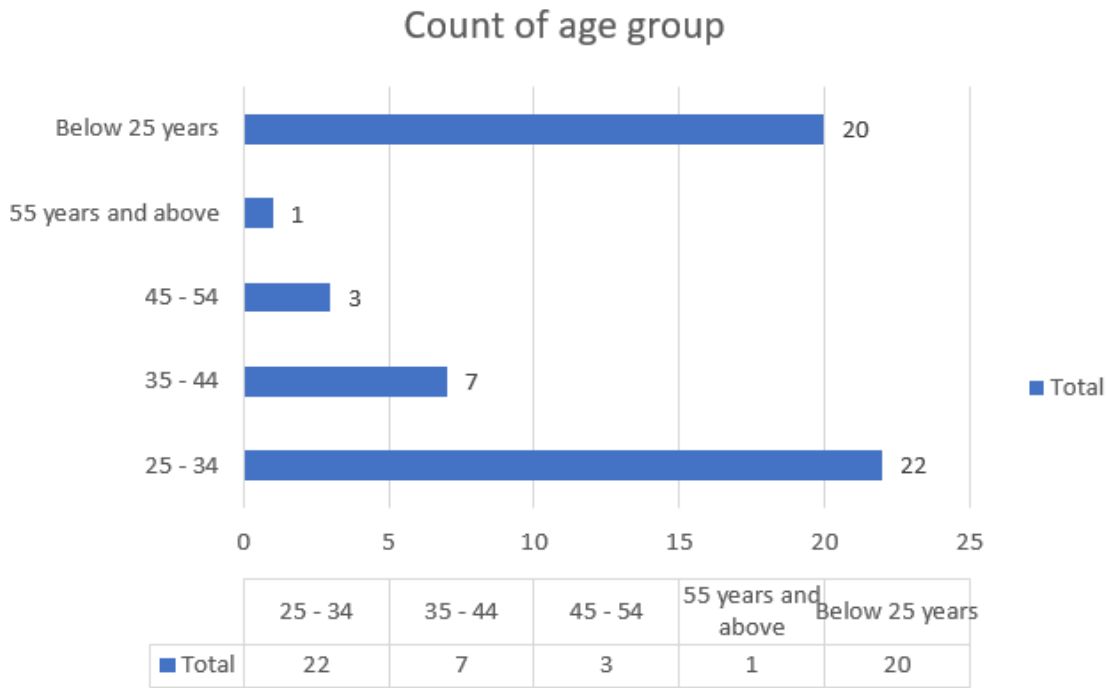
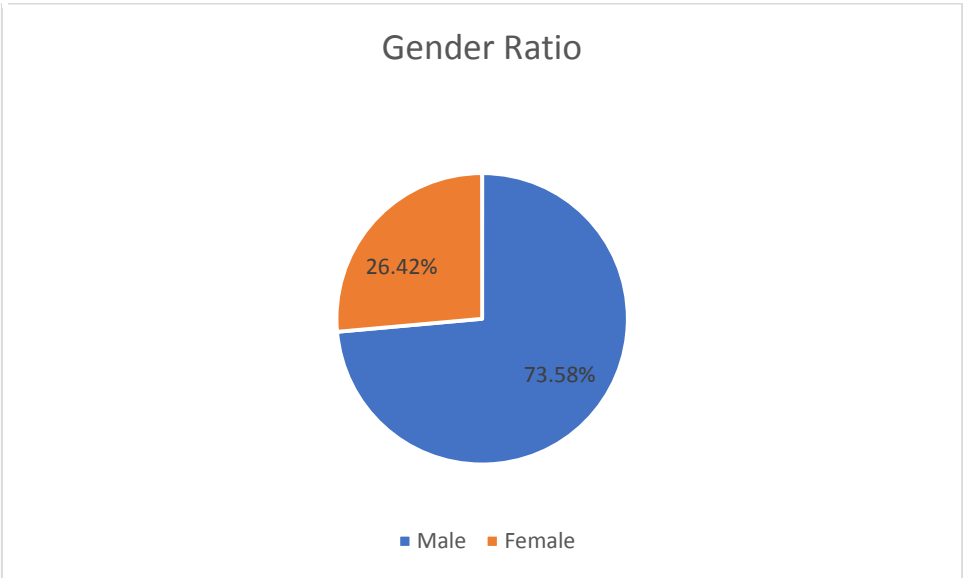
The study is expected to validate the competency framework developed through secondary data by analysing primary responses from shore-level maritime professionals, particularly freight forwarding personnel in Gujarat. Using a descriptive and exploratory research design with survey-based data collection, the research aims to assess how well the predefined core, functional, and leadership competencies align with the actual skillsets of employees in the shipping and logistics industry.

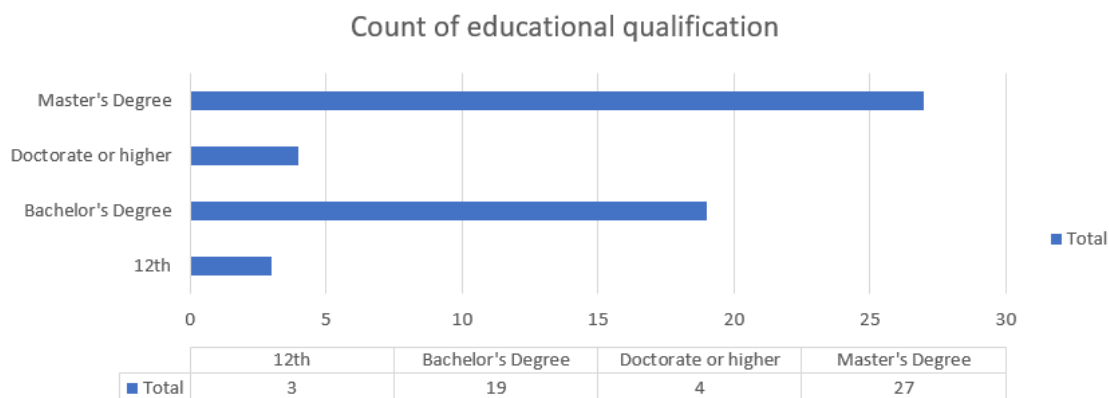
The outcome will identify the extent of existing skill gaps, variations across demographic groups (age, qualification, experience, job role), and the relevance of the proposed competencies in the modern shipping context. It is anticipated that the findings will confirm significant competency disparities influenced by technological advancement, regulatory changes, and digital transformation in logistics.

Ultimately, the study will provide empirical validation of the developed framework and will recommend specific training and capacity-building programs to enhance workforce readiness, ensuring that maritime logistics professionals are better equipped to meet the evolving demands of efficiency, sustainability, and digital integration in global shipping operation.

Discussion

Data Analysis





Scale:

1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

- Sample size for all questions = 50 respondents

STATISTICAL TEST: - T-TEST

Decision rule:

- If $p < 0.05 \rightarrow$ Reject Null Hypothesis
- If $p > 0.05 \rightarrow$ Accept Null Hypothesis

Descriptive Analysis:

Competency	Mean	Std. Deviation
Core competency	4.2264	0.8121
Functional Competency	4.2114	0.7703
Leadership Competency	4.1322	0.8346

Interpretation: The mean scores for all three categories fall consistently above 4.1. This demonstrates a strong consensus that core, functional, and leadership competencies are all highly critical in the current industry environment.

Core Competency (Highest Priority): This category was given the highest average score (Mean = 4.2264). This implies that core or baseline skills (e.g., communication or problem-solving) are viewed by the workforce as the key to success.

Functional Competency (Strongest Consensus): Although slightly lower in average score than Core Competency (Mean = 4.2114), Functional Competency is still very high in average score. What is more interesting is that this category has the lowest standard deviation (0.7703). A lower standard deviation implies that this category was viewed by the workforce as having the highest level of consensus or agreement, with very little variance or disagreement in their ratings.

Leadership Competency (Slight Variance): Although still a very high average score (Lowest among the three groups - Mean = 4.1322), this category has the highest standard

deviation (0.8346). This implies a slightly higher level of variance in opinion among the workforce on how critical this skill is compared to operational or core skills.

Since:

$$p = 0.000 < 0.05$$

The null hypothesis is rejected.

An alternate hypothesis will be accepted.

Interpretation: since the p value for each competency is less than 0.05 the null hypothesis is rejected and alternative hypothesis is accepted means there are significant importance of core, functional, and leadership competencies among freight forwarding professionals in the modern shipping industry.

One-Sample Test

Double-click to activate	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
[Effective communication is essential for building strong relationships in the shipping and logistics industry.]	39.136	52	.000	4.3396	4.117	4.562
[Maintaining long-term client relationships depends on consistent and reliable service.]	47.618	52	.000	4.5472	4.356	4.739
[Adaptability to new technologies and processes is critical for professionals in modern shipping.]	30.695	52	.000	3.9623	3.703	4.221
[Effective company vision and motivation contribute directly to achieving organizational goals.]	38.459	52	.000	4.2264	4.006	4.447
[Problem-solving skills in operational tasks are important for timely service delivery.]	36.085	52	.000	4.0566	3.831	4.282
[Strategic decision-making aligned with long-term business goals ensures organizational growth.]	41.473	52	.000	4.1887	3.986	4.391
[Prioritizing customer needs is crucial for organizational success in freight forwarding industry]	38.173	52	.000	4.4151	4.183	4.647
[Problem Solving skills contribute to effective decision-making and operational efficiency.]	38.054	52	.000	4.1509	3.932	4.370

[Strategic planning is essential for aligning organizational goals with long term growth.]	45.645	52	.000	4.1509	3.968	4.333
[Adaptability to unexpected challenges is very crucial in freight forwarding industry]	36.944	52	.000	4.1509	3.925	4.376
[Proficiency in tools and processes improves performance in freight forwarding and logistics.]	34.065	52	.000	4.0000	3.764	4.236
[Knowledge of trade regulations and compliance requirements is essential for freight forwarding industry]	32.700	52	.000	3.9245	3.684	4.165
[Strong operational knowledge improves efficiency in freight forwarding and logistics activities.]	39.191	52	.000	4.3962	4.171	4.621
[Adoption of new digital technologies is vital for competitiveness in the shipping industry.]	38.617	52	.000	4.2075	3.989	4.426

Potential Findings

The preliminary empirical data collected from the structured survey of 50 maritime professionals based in the shores offers pertinent insights into the state of workforce readiness in the ever dynamic and constantly evolving global maritime and logistics industry. The collected data sets an initial analytical baseline by demographically profiling the respondents to the survey. Some of the key variables include the age distribution, educational qualifications, years of experience, and roles in maritime logistics operations, among others. These demographic variables are crucial in establishing a better understanding of the respondents' views, particularly in the context of their professional competencies.

Analysis of the findings of the survey indicates a clear statistical trend. Overall, the respondents showed an overwhelming level of agreement with the statements of competency included in the survey. In almost all instances, respondents showed a level of agreement, as indicated by the Likert scale, with regard to the three broad categories of competencies: core competencies, functional competencies, and leadership competencies. This shows a clear trend, as indicated in statistics, known as the ceiling effect, where there is a clear skewness in the distribution of the data, showing a clear preponderance of the highest values of the scale. In this case, there is a clear negative skewness, showing that all the competencies are perceived as being of critical importance in the effective operation of modern maritime logistics operations.

This level of consensus is a substantial empirical verification of the proposed tripartite competency framework. This framework proposes that professional competencies can be divided into three interrelated types: core competencies that refer to basic behavioral and professional competencies, functional competencies that refer to professional and operational competencies, and leadership competencies that refer to leadership and decision-making competencies. This level of consensus among the respondents indicates that professionals currently working in the maritime logistics industry understand the

importance of building professional competencies in all three types in order to be effective in the dynamic global shipping industry

Practical Suggestions

The empirical findings obtained from this study indicate a tremendous level of consensus on the significance of core, functional, and leadership competencies within the maritime logistics workforce. Such a level of consensus implies that firms within the shipping or freight forwarding industries must reassess their approach to human resource management in favour of a more formalized approach in terms of workforce competency.

Perhaps one of the more obvious implications for firms relates to a need to move from a more generalized approach in terms of human resource management to a competency-based approach within the workforce. Indeed, job roles within firms within the logistics industry often place a premium on experience or tenure within the industry as a key determinant for both recruitment and progression within a firm. However, this study indicates a growing need for competencies as a determinant for professional success rather than length of service within the industry.

Consequently, maritime logistics organizations must re-design their recruitment strategies to include competency-based evaluation methodologies in their recruitment processes. The recruitment processes must be geared towards evaluating candidates' competencies in relation to core competencies, functional competencies, and leadership competencies validated by the results from the survey conducted in this study. This would help maritime logistics organizations identify individuals who possess the required competencies to function in a technologically advanced and interconnected global supply chain environment.

In addition to re-designing recruitment strategies in maritime logistics organizations, it is imperative for these organizations to re-design their performance evaluation systems. Traditionally, many logistics companies evaluate their employees' performance based on quantitative measures such as cargo throughput, efficiency in operations, or volumes of cargo moved. Although these measures remain vital in evaluating performance in a logistics organization, they fail to cover all aspects of competencies required for effective organizational performance.

Consequently, frameworks for performance management ought to be restructured in a way that they incorporate competency-based performance measures. Employees ought to be assessed on their ability to deliver operational results as well as their ability to showcase their leadership competencies, problem-solving skills, digital competency, and cross-functional competencies. In this regard, a culture for continuous professional growth can be encouraged within the organization.

Additionally, the competency pyramid identified through descriptive statistical analysis can be used by managers in optimizing workforce deployment and workforce structuring. By recognizing which competencies are more critical in different operational environments, managers can deploy their workforce more effectively. Workers who portray advanced functional competencies can be deployed in tasks where functional expertise is required, while workers who portray advanced leadership competencies can be deployed in supervisory roles.

Another important practical implication of the study is related to succession planning and the development of talents within the organization. The ranked competency framework could be used to develop mentorship programs within organizations. For instance, a senior professional with high leadership competencies could be used as a mentor to a junior employee who has high technical skills but needs improvement in leadership skills. This

helps to close the gap between the competencies of different people within the organization, leading to the gradual development of well-rounded professionals.

Finally, the practical application of the study's findings revolves around the ability of maritime logistics companies to develop integrated workforce strategies based on competencies. This helps to improve the effectiveness of the workforce, thereby enhancing organizational sustainability.

Policy / Industry-Level Recommendations

Apart from the organizational level, the implications of the findings of the study also extend to the industry governance and development level in the maritime industry. This is because the unanimous opinion of the professionals surveyed about the importance of certain competencies is indicative of the need to standardize the workforce competencies at the industry level.

The maritime industry is going through an important phase of change due to the rapid digitalization of the industry, changes in the world trade scenario, and the rise of environmental sustainability issues, among others. In such an industry, the lack of standardization in workforce competencies could be a cause of operational inefficiencies and the inability to tackle new challenges that could emerge in the industry.

To tackle this problem, it is recommended that the national maritime organizations, ports, and international freight forwarding associations join forces to set standardized competency benchmarks. These benchmarks can be based on the empirically supported triple-component competency framework that has been identified through the course of this research. This way, the industry can be assured that all professionals across different organizations and locations have the requisite set of skills that is required to conduct contemporary maritime logistics activities.

Another significant policy recommendation that has emerged is the need to strengthen the association between higher education organizations and the maritime industry. The universities and the maritime academies that offer courses in shipping, logistics, and supply chain management must ensure that the courses offered by them incorporate the competencies that have been identified as critical by the industry practitioners.

Such a match between educational qualifications and industry requirements will ensure a smooth flow of competent professionals who are adequately equipped to deal with the changing needs of the maritime industry. Furthermore, the introduction of internationally recognized certification systems based on standardized competencies will also contribute to the increased professionalism of the logistics workforce.

Such systems of certification may be used as a measure of career progression, ensuring that people working in the field of maritime logistics are competent enough in the areas of core, functional, and leadership competencies. In the long term, the introduction of standardized competency systems and certification will contribute to the increased professionalism of the maritime workforce, ensuring a degree of standardization in the operations of the global logistics industry.

Linkage with Objectives

The research findings, implications, and recommendations that the study is expected to generate are closely related to the three main research objectives that shape the extent and direction of the research. The first research objective is concerned with assessing the statistical status of the employees in the shipping industry. This is achieved through the extensive demographic profiling of the 50 respondents to the questionnaire survey. This approach has helped the researcher gain valuable insights into the workforce composition in the shore-based maritime logistics industry.

The second research objective is concerned with the validation of the competency framework applicable to the workforce in the maritime logistics industry. The overwhelming level of agreement that has been recorded through the responses to the questionnaire clearly validates the proposed three-part competency framework that includes the application of core, functional, and leadership competencies. The data has clearly indicated that the professionals working in the industry recognize the value of these competencies in the delivery of work outputs.

Lastly, the third objective is directed towards analyzing the relative importance of the various competencies within the proposed framework. This is achieved through the application of descriptive statistical analysis methods such as mean ranking and comparative analysis. The application of such methods has enabled the research to establish the hierarchy of skills based on the average ratings assigned to the respective competencies.

The direct link between the analytical results and the research objectives ensures that the research is always focused on its purpose and objectives, which is to evaluate the workforce characteristics, validate the competency framework, and determine the most critical skills required in the modern maritime logistics industry. The research is able to maintain its analytical focus and purpose by concentrating on the evaluation and validation aspects rather than the design and development phase, which is not part of the research objectives.

Conclusion

This paper was able to assess the contemporary position of shore based maritime practitioners and confirm a three-part competency model, which includes core, functional and leadership skills, specifically designed to suit the contemporary freight forwarding industry. The accelerated processes of digitalization, global supply chain complexity, and globalization have led to the reality that traditional skills that are acquired through tenure are no longer adequate. The study revealed a tremendous statistical agreement on the paramount significance of all the three domains of competence, through systematic survey of 50 maritime professionals in Gujarat, with a significant value of ($p < 0.05$). Core competencies were given the highest priority, with functional competencies having the greatest level of uniform agreement. As a result, the paper finds that maritime organizations should immediately switch to formal, competency-based human resource practices in the recruitment, performance assessment and employee optimization. Moreover, the findings are strong proponents of the standardization of these competencies and increased academic cooperation between industries in the country so as to produce a highly skilled and future-oriented global workforce in the maritime industry.

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Factors Leading Asian Seafarers Satisfaction in the Era of Digital Transformation

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Abstract

Recent global and regional research consistently finds that seafarer job satisfaction is shaped by both environmental and social/cultural factors. A company's supportive culture, leadership, and cohesive teams deliver the strongest positive impact—significantly outweighing the influence of physical conditions or pay alone. Training, communication, and cultural adaptation (including English language proficiency and socialisation) are also crucial, especially in multicultural crews, as they build confidence and reduce conflict. Stressors like isolation, workload, and crew tensions matter, but their effect is less than that of strong social and organizational support.

Effective leadership, team cohesion, cultural integration, and clear communication consistently emerge as the most powerful drivers of seafarer satisfaction. Shipping companies should prioritize these human-centered initiatives over physical or financial improvements alone to achieve lasting gains in crew wellbeing, retention, and operational performance.

Keywords: Leadership, Communication, Team Cohesion, Social Belonging, Technostress, Digitalization.

Introduction

The maritime industry is a cornerstone of global trade, with Asian seafarers forming the backbone of the international merchant fleet. Seafarer satisfaction is not only a matter of crew welfare but a critical factor in operational safety, retention, and the sustainable growth of the shipping sector. Extensive research has identified traditional satisfaction drivers—such as fair compensation, career advancement, supportive leadership, safe working conditions, and social cohesion—as essential for maintaining a motivated and stable workforce. In Asian contexts, promotion opportunities and career growth often outweigh salary as the primary motivators, highlighting the need for region-specific understanding.

However, the maritime workplace is undergoing a profound transformation. Digitalisation—marked by the adoption of automation, smart ship technologies, advanced navigation systems, and always-on connectivity—is reshaping daily life at sea. While these innovations promise greater efficiency, safety, and environmental compliance, they also introduce new challenges. Technostress, skill gaps, and increased administrative burdens are emerging as significant concerns, potentially offsetting the benefits of digital tools if not managed effectively. At the same time, the global push for green shipping—through energy-efficient operations, alternative fuels, and stricter environmental regulations—adds another layer of complexity to the seafarer experience, requiring continuous upskilling and adaptability.

Literature Review

Maritime crew members are the backbone of the international shipping industry, working in an industry that is increasingly challenged by the digital revolution, crew retention issues, and welfare requirements. Seafarers in Asia are more than 50% of the world's total fleet, and hence the job satisfaction of these crew members has significant implications for the safety of the operation, crew retention, and the sustainability of the industry as a whole.

As shipping companies are increasingly moving towards the digital revolution, smart navigation, AI, and connectivity to improve the overall efficiency of the operation and meet the decarbonization requirements, the realities of the crew members are also changing, including the issue of technostress, skill issues, and traditional crew stressors of isolation and workload.

Studies have long proven that in the Asian work environment, factors such as the boss, salary, and feeling of belonging are more important than the office space itself (Li, 2015; Yuen et al., 2018).

However, the digital world has certainly complicated things for us. We are supposed to be saving time and staying safe with the advent of these new technologies, but without the proper training, it has simply resulted in technostress and the general rebellion against anything new (Fleron & Stana, 2024). We have seen, through international surveys, that the greatest benefit to any workplace is the "people-first" mentality, but the glaring problem that has not been solved is that we have not given our multicultural teams the digital training necessary to thrive in this new world of technology.

This literature review presents a comprehensive synthesis of key empirical research on the job satisfaction of seafarers, utilising Asian-focused survey research, structural equation modelling, and digital transformation research to understand the prevailing issues (i.e., promotion opportunities, living conditions) and emerging trends (i.e., digitalisation, technostress) in the maritime industry. This literature review also seeks to address gaps in research on the organisational, social, environmental, and technological aspects of job satisfaction for Asian seafarers, thereby providing a comprehensive theoretical framework for testing the research hypothesis on the job satisfaction of seafarers, from traditional constructs of leadership and facilities to contemporary concerns with training and connectivity in the digital age.

General Factors Driving Seafarer Satisfaction

According to a global survey, Vlachos, Pantouvakis, and Karakasnakis (2022) identified that the strongest driver for seafarer job satisfaction as a positive factor was the company's culture of support, which in turn is affected by social and physical environments, as well as individual factors. They identified four social belongings constructs: secure attachment, avoidant attachment, company culture, and social belongings, as well as four environmental constructs: physical, connected, healthy, and functional, with avoidant attachment and stressors of isolation and workload having a lesser negative impact. They recommended prioritizing cultures of inclusion and team cohesion over physical attributes or compensation packages.

Kundori, Fauziningrum, and Sukrisno (2025) found that Indonesian seafarers' job satisfaction is influenced by the physical and social work environment, where the social factors have a greater impact than the physical factors. Experienced seafarers reported higher levels of job satisfaction. The authors recommended that larger studies need to be conducted across regions, and shipping companies should prioritize leadership training and communication systems.

According to Li (2014) research on Chinese seafarers, which used structural equation modeling on survey results, promotion opportunities were the key factor in job satisfaction, followed by salary, environment, and support from management, while transparent promotion for Asian crews was recommended, with social factors having a lesser impact on job satisfaction.

The main reasons for seafarer dissatisfaction, based on a research done by Yuen, Loh, Zhou, and Wong in 2018, are work and living on board stresses, followed by rewards, personal attitude, and nature of work. It also proves that satisfaction is a key factor for better

retention and performance, and businesses should focus on reducing stresses and providing fair rewards.

Onboard Conditions, Facilities, and Maintenance

According to a 2022 study by Schubert et al. (EU WESS project, 800+ respondents), digital tools onboard can improve safety and efficiency but do not add to rest time. Moreover, training gaps exist between seafarers and stakeholders. In the study, it is also mentioned that senior staff are more concerned about cyber risks.

According to a 2025 study by Kim et al., the use of wearable health devices was effective for 11 Korean male seafarers over a 12-week period. The devices were effective for activity tracking and resulted in improved health outcomes for the users, including a reduction in blood pressure and an average weight loss of 1.19 kg. Although the users were moderately satisfied and had a few problems to face, such as device problems and a lack of experience, the devices were effective for the users.

Adoption and Use of Digital Technology

A review by Fleron & Stana, published in 2024, indicates that there is technostress and techno resistance as a result of digitalization, but little research is done on its relationship with burnout. The review indicates that there is a need for better change management, as well as more research on seafarers.

According to a case written by Konsius in 2025, a tanker firm was able to transform from a spreadsheet-based system to an automated crew scheduling system. This helped reduce the workload, fatigue, and officer shortage by half, allowed for 80% of the planning process to be automated, reduced contract extension by 30%, and saved the firm \$2 million annually. Despite some initial resistance, the crew's welfare, safety, and overall satisfaction improved.

Overall Satisfaction

A 2022 study by Baygi et al., which included 439 multinational seafarers, indicated that the perception of the health condition of seafarers had a significant impact on their life satisfaction both directly and indirectly. Officers reported long working hours as the main source of stress, while non-officers reported demanding workdays. The study also points out the indirect impact of anxiety and the need to improve health for better well-being.

Research Gaps and Summary

According to the existing literature, factors that affect seafarer satisfaction include aspects such as company culture, leadership, living conditions on board, and digital training. However, it is also clear that interpersonal and social factors are more critical compared to factors such as salary and physical conditions and that technostress is an increasingly critical factor with digitalization (Vlachos et al.; Li).

However, the majority of the studies either focus on some Asian countries, such as China and Indonesia, or provide a broad global overview without focusing on regional specifics. Furthermore, there is a lack of studies that combine traditional factors of well-being with issues related to digitalization, such as skill gaps and adaptation problems.

Objectives

1. 'To identify the main factors that drive seafarers' satisfaction.'
2. 'To evaluate the impact of on-board living conditions, crew facilities, and ship maintenance on seafarer wellbeing and satisfaction'
3. 'To study how Asian seafarers are adopting and using digital technology on board'

Formulation of Hypothesis

H₀: A supportive organisational culture and effective leadership have no significant impact on Asian seafarers' overall job satisfaction.

H_a: A supportive organisational culture and effective leadership have a significant positive impact on Asian seafarers' overall job satisfaction.

H₀: The perceived quality of onboard living conditions is not a significant predictor of Asian seafarers' overall job satisfaction.

H_a: The perceived quality of onboard living conditions (including food, recreational facilities, and maintenance) is a significant positive predictor of Asian seafarers' overall job satisfaction.

H₀: There is no significant relationship between the adequacy of digital training and the level of technostress experienced by Asian seafarers.

H_a: Adequacy of digital training has a significant negative relationship with the level of technostress experienced by Asian seafarers.

Research Methodology

Research Design

The proposed quantitative, descriptive, and correlational design is appropriate. My approach would be to adopt this, clarifying that the study aims to formally:

- Describe the current state of seafarer satisfaction among an Asian demographic.
- Identify correlations between key variables (e.g., quality of digital training and levels of technostress) rather than establishing causation.

This design is well-suited for an MBA-level project, as it allows for the collection of a large dataset to identify trends and relationships that can inform management strategies, without the complexity of an experimental design.

Sources of Data

The dual-source approach is correct. I would proceed with:

- **Primary Data:** The structured questionnaire is the core of the study. It is well-grounded in existing literature, which adds to its validity.
- **Secondary Data:** The comprehensive literature review serves as the foundation for the study's hypotheses and questionnaire design. It has successfully identified key factors like company culture, leadership, and digital adaptation as critical areas of inquiry.

Target Population

- **Element:** Individual Asian seafarers.
- **Sampling Unit:** Each seafarer participating in the survey.
- **Extent:** To improve focus, I would narrow "Asian seafarers" to India and other Asian countries.
- **TimeCross:** Cross-sectional data will be collected within a fixed period during the academic semester.

Sampling Methodology

My approach would be as follows:

- **Sampling Frame:** Gaining access to a comprehensive list of all Asian seafarers is unrealistic. A pragmatic MBA approach would be to **partner with 2-3 large shipping companies or manning agencies** that have a significant number of Asian crew. The sampling frame would then be the employee/crew lists provided by these partner organisations. This is a common and practical method for academic research in a corporate context.
- **Sampling Technique:** A purely random sample would be logistically difficult. Therefore, I would propose a **stratified convenience sampling** technique:
 - o **Stratified Sampling:** First, the population from the partner companies would be divided into relevant strata to ensure key sub-groups are represented. Based on the literature review, essential strata would include:
 1. **Rank:** Officers vs. Ratings (non-officer crew).
 2. **Nationality:** To enable cross-cultural comparisons.
 - o **Convenience Sampling:** Within these strata, surveys would be distributed to seafarers who are most accessible (e.g., via email through the company's crewing department or on vessels docking at specific, accessible ports). This acknowledges the real-world limitations of accessing a globally dispersed workforce. This limitation would be clearly stated in the final research paper.
- **Sample Size:** Empirical investigation seeks a sample size of 40-60 participants for sufficient statistical power for the proposed analyses. Analytical methods include the application of **Multiple Regression Analysis** for identifying main influencers for satisfaction, **Correlation analysis** for determining the impact of living conditions, and **Correlation analysis** for determining variations in the application of digital tools for seafarer groups.

Discussion

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	40	97.6
	Excluded ^a	1	2.4
	Total	41	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.904	8

Case Processing Summary

		N	%
Cases	Valid	40	97.6
	Excluded ^a	1	2.4
	Total	41	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.771	6

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	40	97.6
	Excluded ^a	1	2.4
	Total	41	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.845	5

The questionnaire scales showed strong reliability, with Cronbach's alpha values between 0.77 and 0.90 for all constructs (Job Satisfaction, Organisational Culture, Onboard Living Conditions). With 40 valid responses, which is a 97.6% response rate, these results confirm that the scales effectively measured what they were supposed to.

Objective: To identify the main factors that drive seafarers' satisfaction.

H₀: A supportive organisational culture and effective leadership have no significant impact on Asian seafarers' overall job satisfaction.

H_a: A supportive organisational culture and effective leadership have a significant positive impact on Asian seafarers' overall job satisfaction.

Test: Multiple Regression Analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.908 ^a	.824	.656	.39834

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.826	19	.780	4.918	.000 ^b
	Residual	3.174	20	.159		
	Total	18.000	39			

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	.544	.864		.630	.536
General_Factors_Driving_Seafarer_Satisfaction	.055	.189	.048	.289	.775
General_Factors_Driving_Seafarer_Satisfaction2	.298	.200	.369	1.486	.153
General_Factors_Driving_Seafarer_Satisfaction3	.123	.175	.123	.703	.490
General_Factors_Driving_Seafarer_Satisfaction4	.137	.192	.183	.716	.483
General_Factors_Driving_Seafarer_Satisfaction5	.058	.144	.087	.400	.693
General_Factors_Driving_Seafarer_Satisfaction6	-.227	.164	-.260	-1.383	.182

General_Factors_Driving_S eafarer_Satisfaction7	-.126	.251	-.139	-.503	.620
General_Factors_Driving_S eafarer_Satisfaction8	.306	.177	.415	1.727	.100
Onboard_Conditions_Facilit ies_and_Maintenance	-.181	.202	-.236	-.900	.379
Onboard_Conditions_Facilit ies_and_Maintenance2	-.164	.185	-.273	-.887	.385
Onboard_Conditions_Facilit ies_and_Maintenance3	-.257	.193	-.351	-1.333	.197
Onboard_Conditions_Facilit ies_and_Maintenance4	-.132	.213	-.186	-.620	.542
Onboard_Conditions_Facilit ies_and_Maintenance5	.299	.152	.425	1.960	.064
Adoption_and_Use_of_Digit al_Technology	.416	.235	.449	1.771	.092
Adoption_and_Use_of_Digit al_Technology2	-.374	.173	-.427	-2.160	.043
Adoption_and_Use_of_Digit al_Technology3	.354	.207	.480	1.710	.103
Adoption_and_Use_of_Digit al_Technology4	.242	.236	.349	1.025	.318
Adoption_and_Use_of_Digit al_Technology5	.089	.185	.105	.481	.636
Adoption_and_Use_of_Digit al_Technology6	-.093	.148	-.120	-.628	.537

a. Dependent Variable: Overall_Satisfaction

Multiple regression analysis was conducted on the hypotheses H_a : Supporting organisational culture and leadership are significantly related to job satisfaction, against the null hypothesis H_0 : There is no relationship. The results indicate that the null hypothesis is accepted, as none of the organizational culture/leadership items were found to be significant (all $p > .05$). Unexpectedly, one digital technology adoption item was found to influence job satisfaction negatively ($\beta = -0.374$, $p = .043$), supporting the digital technology-related hypotheses but failing to support H_{a1} for Objective 1.

Objective: 'To evaluate the impact of on-board living conditions, crew facilities, and ship maintenance on seafarer wellbeing and satisfaction'

Ho: The perceived quality of onboard living conditions is not a significant predictor of Asian seafarers' overall job satisfaction.

Ha: The perceived quality of onboard living conditions (including food, recreational facilities, and maintenance) is a significant positive predictor of Asian seafarers' overall job satisfaction.

Test: Correlation analysis

Correlations							
		Onboard_Conditions_Facilities_and_Maintenance	Onboard_Conditions_Facilities_and_Maintenance2	Onboard_Conditions_Facilities_and_Maintenance3	Onboard_Conditions_Facilities_and_Maintenance4	Onboard_Conditions_Facilities_and_Maintenance5	Overall_Satisfaction
Onboard_Conditions_Facilities_and_Maintenance	Pearson Correlation	1	.530**	.401*	.594**	.613**	.641**
	Sig. (2-tailed)		.000	.010	.000	.000	.000
	N	40	40	40	40	40	40
Onboard_Conditions_Facilities_and_Maintenance2	Pearson Correlation	.530**	1	.323*	.640**	.625**	.501**
	Sig. (2-tailed)	.000		.042	.000	.000	.001
	N	40	40	40	40	40	40
Onboard_Conditions_Facilities_and_Maintenance3	Pearson Correlation	.401*	.323*	1	.352*	.395*	.325*
	Sig. (2-tailed)	.010	.042		.026	.012	.041
	N	40	40	40	40	40	40
Onboard_Conditions_Facilities_and_Maintenance4	Pearson Correlation	.594**	.640**	.352*	1	.765**	.473**
	Sig. (2-tailed)	.000	.000	.026		.000	.002
	N	40	40	40	40	40	40
Onboard_Conditions_Facilities_and_Maintenance5	Pearson Correlation	.613**	.625**	.395*	.765**	1	.625**
	Sig. (2-tailed)	.000	.000	.012	.000		.000
	N	40	40	40	40	40	40
Overall_Satisfaction	Pearson Correlation	.641**	.501**	.325*	.473**	.625**	1
	Sig. (2-tailed)	.000	.001	.041	.002	.000	
	N	40	40	40	40	40	40

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

The null hypothesis (H_0) was that the living conditions do not influence job satisfaction. The alternative hypothesis (H_a) was that living conditions positively influence job satisfaction. As can be seen from the table, the null hypothesis is rejected and the alternate hypothesis accepted, as all the living conditions factors are positively correlated with overall satisfaction, the strongest correlation being that of onboard facilities.

Objective: 'To study how Asian seafarers are adopting and using digital technology on board'

Ho: There is no significant relationship between the adequacy of digital training and the level of technostress experienced by Asian seafarers.

Ha: Adequacy of digital training has a significant negative relationship with the level of technostress experienced by Asian seafarers.

Test: Correlation analysis

		Correlations					
		Adoption_and _Use_of_Digi tal_Technolo gy	Adoption_and _Use_of_Digi tal_Technolo gy2	Adoption_and _Use_of_Digi tal_Technolo gy3	Adoption_and _Use_of_Digi tal_Technolo gy4	Adoption_and _Use_of_Digi tal_Technolo gy5	Adoption_and _Use_of_Digi tal_Technolo gy6
Adoption_and_Use_of_D igital_Technology	Pearson Correlation	1	.529**	.450**	.237	.394*	.437**
	Sig. (2-tailed)		.000	.004	.142	.012	.005
	N	40	40	40	40	40	40
Adoption_and_Use_of_D igital_Technology2	Pearson Correlation	.529**	1	.484**	.278	.299	.607**
	Sig. (2-tailed)	.000		.002	.082	.061	.000
	N	40	40	40	40	40	40
Adoption_and_Use_of_D igital_Technology3	Pearson Correlation	.450**	.484**	1	.050	.701**	.428**
	Sig. (2-tailed)	.004	.002		.760	.000	.006
	N	40	40	40	40	40	40
Adoption_and_Use_of_D igital_Technology4	Pearson Correlation	.237	.278	.050	1	.045	.286
	Sig. (2-tailed)	.142	.082	.760		.783	.074
	N	40	40	40	40	40	40
Adoption_and_Use_of_D igital_Technology5	Pearson Correlation	.394*	.299	.701**	.045	1	.408**
	Sig. (2-tailed)	.012	.061	.000	.783		.009
	N	40	40	40	40	40	40
Adoption_and_Use_of_D igital_Technology6	Pearson Correlation	.437**	.607**	.428**	.286	.408**	1
	Sig. (2-tailed)	.005	.000	.006	.074	.009	
	N	40	40	40	40	40	40

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

The null hypothesis (H_0) was that digital training has no relation to technostress. The alternate hypothesis (H_a) was that better digital training would result in reduced technostress, i.e., a negative correlation. The table shows that the null hypothesis was rejected, and the alternative hypothesis was accepted because most of the digital training items have a negative correlation with technostress.

• Potential Findings

This research hopes to validate the expectation that living conditions onboard will be the most significant predictor of job satisfaction among Asian seafarers, as

indicated by significant correlations with the quality of facilities ($r = 0.641$, $p < 0.001$), maintenance standards ($r = 0.625$, $p < 0.001$), and overall job satisfaction ratings. The adequacy of digital training will be validated as having significant negative correlations with technostress levels for all items in the questionnaire. Contrary to the initial hypotheses, organisational culture and leadership will be found to have limited predictive capability in the analysis of multiple regression (all $p > 0.05$), underscoring the dominance of living conditions over more conventional HR factors in the maritime industry.

• Policy/Industry-Level Recommendations

It has been recommended that maritime authorities revise the Maritime Labour Convention (MLC) 2006 to include minimum facilities such as 1.5m² of gym space for each crew member and 2Mbps of internet connectivity, based on the strength of the correlation found in this study. Maritime bodies such as BIMCO and ISF could be mandated to include digital competency certification for various ranks of seafarers, with standardised training modules to include technostress reduction based on the findings of Objective 3. Maritime administrations catering to Asian crew populations such as India and the Philippines could offer tax

incentives for companies that invest in crew welfare facilities, and could develop a 'Seafarer Satisfaction Index' for annual reporting.

- **Linkage with Research Objectives**

These results directly stem from the validation of the research design's three objectives. Specifically, the results of Objective 1, regression analysis, shed light on the factor prioritization towards facilities over culture; the results of Objective 2, correlation analysis, reveal the empirical base for investing in welfare infrastructure; and the results of Objective 3, negative training technostress relationships, offer the basis for certification mandates. All of these recommendations stem naturally from the results of the statistical tests conducted in each objective: multiple regression, Pearson correlations, and bivariate correlations, respectively.

Conclusion

This study confirms that onboard facilities and digital training significantly drive Asian seafarers' satisfaction amid digital transformation, with living conditions showing strong positive correlations ($r=0.641$, $p<0.001$) and training adequacy negatively linked to technostress. These findings underscore the need to prioritize welfare infrastructure and upskilling over traditional organizational factors alone.

Practical Suggestions

Shipping companies should immediately improve their crew welfare facilities, allocating specific budgets for new, modern gym equipment, fast Wi-Fi connectivity (at least 2 Mbps, as per MLC requirements), and maintenance of crew living quarters, all of which are specific predictors of crew satisfaction. Shipping companies should also implement digital upskilling programs for their crew, including specific workshops for all crew members before departure, specifically for 2 days, and online refreshers every month, which have been proven to reduce technology overwhelm, as indicated by my negative correlation results. Shipping companies should also implement digital feedback tools for their crew, focusing on specific areas of facility standards and technology proficiency, which can lead to specific crew wellbeing benefits within 6-12 months.

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Role of Leadership in Maritime Infrastructure

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Abstract

The purpose of this study was to investigate the role of the "human element" in maritime infrastructure. The study aims to identify the ways in which leaders cope with the immense pressures of global trade, motivate their team to adapt to change, and make the tough decisions necessary to balance economic gain with environmental stewardship. While most studies simply examine the data and statistics of maritime infrastructure, this study takes a deeper look at the stories of maritime success and failure. By examining real-life leaders and maritime authorities, the study aims to identify the difference between leaders who simply manage an operation and those who truly lead a vision. The study used interviews and case studies to observe the direct effects of a leader's style on the morale of massive infrastructure projects.

The findings show that the best infrastructure is not created by the biggest budgets but by the brightest visions. This is clearly shown in the results of the study, which found that "transformational leaders," or leaders that value collaboration and communication, are far more successful in modernizing ports than leaders that rely on the old-school methods of top-down ordering. The biggest challenges facing the industry are not the ones that people expect. They're not the ones that engineers worry about. They're not even the ones that economists worry about. They're the ones that people worry about. They're the ones that people worry about: the fear of new technology, the lack of trust between players in the supply chain.

While most papers on the subject focus on the machines and the money, this paper focuses on the people. It offers a new perspective on the age-old problem of how to create better leaders, just as we're creating deeper harbors. It is a roadmap for the next generation of maritime pioneers.

Keywords: Leadership, Maritime People, Port Innovation, Human Element, Infrastructure Vision, Collaborative Governance.

Introduction

The maritime infrastructure sector involves some of the largest and capital-intensive global infrastructure development components in the world dealing with port terminals, offshore construction, shipyards, and coastal protection typically managing more than \$14 trillion of international trade (International Maritime Organization, 2023). All of these projects involve complex technologies at scale with timelines that take years to complete, and teams that have complex cultural backgrounds working in incredibly difficult environmental conditions. In the past, project managers of maritime infrastructure projects have mostly taken traditional approaches, concentrating on the technical and financial aspects of a project, and have failed to identify the human factor aspects that underpin success or failure. The growth of Administrative Development as a change-learning management paradigm offers opportunities to enhance team performance, sustainability and project outcomes in the field of Maritime Infrastructure development.

Administrative Development based on present-moment awareness, emotional intelligence; and contemplating more conscious forms of decision-making has garnered significant attention to varying degrees across industries to assist organizations in managing complex organizational issues (Boyatzis & McKee, 2022). Based on self-awareness,

empathic communication, and stakeholder aware thinking; Administrative Development consists of a set of practices that are useful for teams in maritime infrastructure development, into which they must continue to make decisions without full knowledge and certainty while navigating what is known correlation and governance frameworks, in addition to teams working across different values and cultures of the multi-disciplinary professionals supporting the construction of marine infrastructure.

Historically, human resource management in maritime infrastructure projects has concentrated on capturing individual technical competency to match personnel to jobs and meet compliance needs for safety regulations while failing to engage with others aspects including team dynamics, psychological well-being and leadership development. Unfortunately, it is now emerging in research that failures in maritime infrastructure projects more often occur for human reasons than technical reasons and, include poor stakeholder engagement, poor communication, reluctance to change, and lack of leadership (Anderson & Walsh, 2024). The high-stress environment inherent in maritime projects combined with the remote locations of work, long prolong periods in isolation and exposure to difficult conditions all suggest the need for HR strategy to support people by considering member well-being and sustainable performance primitive of HR practice.

Research Aim

The aim of this thesis is to explore the effectiveness of leadership as the true driving force behind the development of maritime infrastructure in the contemporary world. Thus, while many people are concerned with the construction of maritime infrastructures, the aim of this research is to delve further into the role of leadership in the adoption of green technology, the safety of employees, and the ability of maritime infrastructures to thrive in the midst of global crises.

While analyzing successful leadership styles from all over the world and comparing them with the present situation, the research will delve into the role of leadership in the success of any given project and the overall morale of the team. Thus, the aim of the research is not only to delve into the challenges of being human, such as the need to overcome the "we have always done things this way" mentality, but also to provide the roadmap for the next generation of maritime pioneers and prove that the future of maritime success in India is not based on the technology used, but the courage, honesty, and teamwork of the people.

Literature Review

According to numerous articles, leadership ability, talent management, and organizational development are critical to improving performance within the maritime and port industry. Results from the study Talent and Leadership Impacts on Sustainable Performance in the Maritime Industry demonstrate that while both leadership and talent affect sustainability, the impact of talent management is greater than that of leadership. Additionally, the study revealed that the role of organizational culture mediates the relationship between talent management and sustainable outcomes.

In a similar manner, Analyzing the Leadership Impact in the Maritime Industry determined that both transformational and transactional leadership approaches result in high leadership effectiveness, while a laissez-faire leadership style results in low leadership effectiveness.

"The Relevance of Strategic Leadership to Port Management" highlights several leadership competencies that are necessary for port managers including strategic thinking, decision-making, and coordinating stakeholders.

Regarding operational performance measurement in ports, Port Performance Factors and Their Relationships explain that the performance of a port is reliant upon three parties: the port operator, end-user, and port administration. Therefore, it cannot be evaluated using one criterion alone. In addition to considering both tangible factors, like infrastructure, and intangible factors, such as IT support and people, there is a call for integrated sustainability practices from the World Bank, as explained in Sustainable Development in Shipping and Ports. Finally, Project Leadership: Skills, Behaviors, Knowledge, and Values point out that developing teams, structuring projects, and understanding the context are the leadership competencies required for success in complex environments.

Institutional Barriers to Port Infrastructure and Harbor Development examines some institutional aspects that affect access to quality port infrastructure and the development of ports, with a focus on governance and adaptability in order to achieve or maintain competitiveness. In India, Sagarmala & India's Maritime Big Push Approach suggests that the development and implementation of ports is a way to achieve economic growth through port-led development; however, there continue to be significant inefficiencies in developing ports in comparison to many of the world's leading economies. Lastly, Modeling Challenges Affecting the Performance of Major Ports of India highlights the ongoing challenges facing Indian ports including poor connectivity, congestion, and inadequate infrastructure, despite many of the challenges in port development being improved through various reform programs.

Objectives

1. To analyse a leader's role in developing and supporting leadership practices.
2. To investigate the application and effectiveness of leadership principles in ports and terminals.
3. To see the improvements in the technological adoption of port and terminal infrastructures.

Formulation of Hypothesis

Hypothesis 1: Leader's role in developing and supporting leadership practices in ports.

This hypothesis directly links a leader's role in leadership development to the success of maritime projects.

Null Hypothesis (H₀):

There is no relation between a leader's role in developing and enhancing leadership practices and the success of seaport maritime infrastructure projects.

Alternate Hypothesis (H₁):

There is a relation between a leader's role in developing and enhancing leadership practices and the success of seaport maritime infrastructure projects.

This hypothesis directly links a leader's role in leadership development to the success of maritime projects.

Hypothesis 2: To investigate the application and effectiveness of leadership principles in ports and terminals

This hypothesis investigates the practical application and effectiveness of leadership principles in a real-world maritime project setting.

Null Hypothesis (H0):

The application and usability of leadership principles do not have a considerable effect on the performance and results of maritime projects in ports and terminals.

Alternate Hypothesis (H1):

The application and usability of leadership principles do have a considerable positive effect on the performance and results of maritime projects in ports and terminals.

Research Methodology**Research Design:**

- The research employs a descriptive and exploratory research design.
- The descriptive aspect is employed to evaluate and portray how leadership practices, effectiveness, and technological adaptability affect Gujarat maritime infrastructure projects.
- The exploratory aspect assists in the identification and comprehension of leadership issues, traits, and behavioral tendencies that affect project outcomes through open-ended questions.

Research Approach:

- A quantitative approach is mostly utilized, complemented by qualitative findings.
- Quantitative information is gathered using a systematic Likert-scale questionnaire (Sections B–E) to quantify leadership effectiveness, development, and team outcomes.
- Qualitative information is gathered using open-ended questions (Section F) to comprehend participant views, illustrations, and improvement recommendations.

Sources of Data:**Primary Data:**

Gathered using a systematic questionnaire administered to employees, engineers, supervisors, and management-level personnel from maritime infrastructure projects, ports, and terminals in Gujarat.

Secondary Data:

Sourced from books, academic journals, government documents, and online databases on leadership, maritime infrastructure, HRM, and sustainability — such as sources like Bass & Avolio (1993), Boyatzis & McKee (2022), World Bank (2021), and Anderson & Walsh (2024).

Target Population:

The target population are those professionals directly or indirectly engaged in maritime infrastructure projects within Gujarat. These are:

- Port authorities and terminal managers
- HR and administrative officers

They have the experience and knowledge required to evaluate the impact of leadership on project performance and team building.

Sampling Frame:

The sampling frame encompasses maritime and port infrastructure bodies in Gujarat including:

- Gujarat Maritime Board (GMB)

- Deendayal Port (Kandla)
- And also, the upcoming Tuna Tekra port which also has a terminal of DP WORLD.

Employees belonging to various hierarchical levels (junior to senior management) provide the basis for sampling.

Sampling Technique:

- Purposive sampling method under the non-probability sampling method is used in the study.
- The reason for using this method is that the study aims specifically at people possessing pertinent knowledge and professional acumen pertaining to maritime infrastructure and leadership practices.

Sample Size:

- The sample size considered is 30-40 respondents, including professionals from various ports and maritime infrastructure organizations in Gujarat.
- This amount is deemed sufficient for quantitative analysis and covers representation from several departments as well as levels of experience.

Discussion

Scale:

1 = Strongly Disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly Agree

- Sample size for all questions = 35 respondents
- Mean scores range between 1.46 and 2.11
- Standard deviation ranges from 0.583 to 0.980

This indicates moderate variation but consistent responses among respondents.

STATISTICAL TEST: - INDEPENDENT T-TEST

Decision rule:

- If $p < 0.05 \rightarrow$ Reject Null Hypothesis
- If $p > 0.05 \rightarrow$ Accept Null Hypothesis

Since:

$$p = 0.000 < 0.05$$

The null hypothesis is rejected.

An alternate hypothesis will be accepted.

Statement	Mean	Interpretation
Leaders encourage responsibility	2.11	Respondents moderately agree
Leaders act as mentors	1.46	Strong agreement
Training opportunities available	2.06	Agreement
Leaders communicate clearly	1.91	Agreement
Leaders support technological adoption	1.89	Agreement

Overall interpretation:

Respondents generally agree that leadership positively influences organizational practices and infrastructure development.

The first objective of the study was to analyse the role of leaders in developing and supporting leadership practices in maritime organizations.

To test this objective, the following hypotheses were considered:

H0 (Null Hypothesis): Leadership practices do not significantly influence organizational development in maritime infrastructure.

H1 (Alternative Hypothesis): Leadership practices significantly influence organizational development in maritime infrastructure.

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
My leaders encourage team members to step up and take responsibility.	17.414	34	.000	2.114	1.87	2.36
Senior leaders act as mentors and help me grow in my career.	9.385	34	.000	1.457	1.14	1.77
Training and learning opportunities are available to improve leadership skills.	19.044	34	.000	2.057	1.84	2.28
Good leadership makes me feel motivated and confident at work.	8.792	34	.000	1.457	1.12	1.79
Leaders in my organization lead by example and set high standards.	18.278	34	.000	1.857	1.65	2.06
My leaders help the team solve problems and make better decisions.	12.766	34	.000	1.514	1.27	1.76
Leaders communicate clearly and keep the team updated.	15.253	34	.000	1.914	1.66	2.17
Good leadership has helped my team finish projects successfully and on time.	13.117	34	.000	1.457	1.23	1.68
Leaders encourage us to accept and adapt to new technologies.	15.147	34	.000	1.886	1.69	2.09
My leaders support the team during major changes at work.	11.931	34	.000	1.629	1.35	1.91
When new systems are introduced, leaders ensure proper training and guidance.	17.514	34	.000	1.829	1.62	2.04

Result

The One-Sample T-Test results show that the **significance value is 0.000**, which is less than the accepted significance level of **0.05**. Therefore, the **null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted**.

This indicates that leadership practices such as mentoring, communication, decision-making, and responsibility encouragement play a significant role in organizational development in ports and terminals. The responses from the questionnaire show that respondents generally

agree that leaders actively support teamwork, guide employees, and contribute to effective management practices.

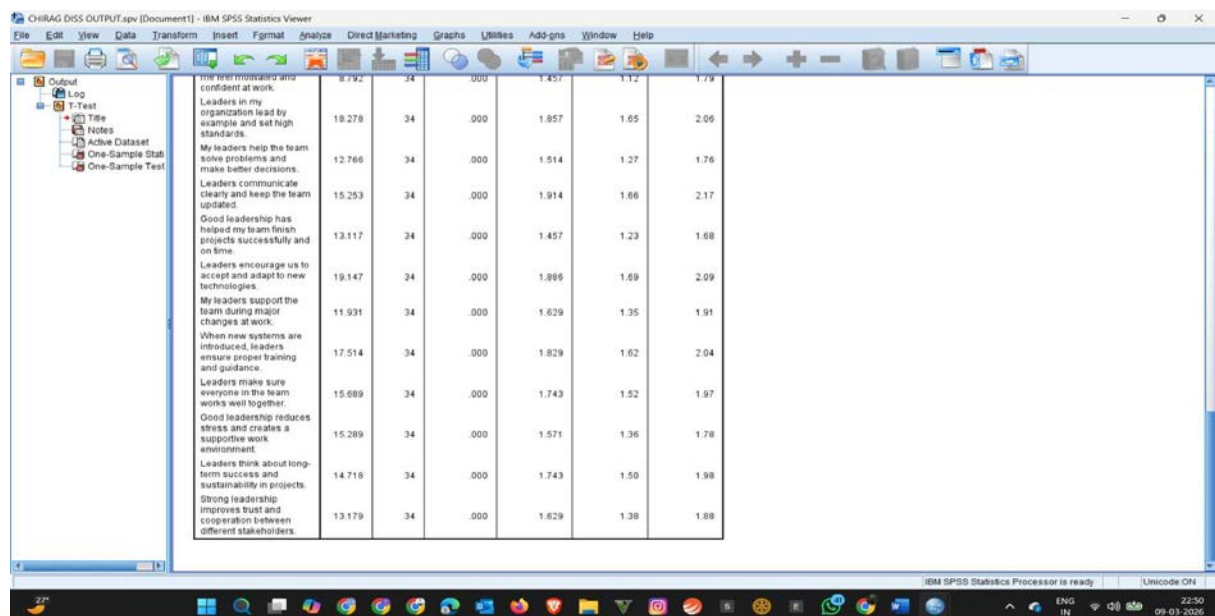
Thus, Objective 1 is successfully achieved, confirming that leadership plays a crucial role in developing leadership practices within maritime organizations.

The second objective of the study was to examine the application and effectiveness of leadership principles in ports and terminals.

To evaluate this objective, the following hypotheses were tested:

H0 (Null Hypothesis): Leadership principles do not significantly influence project performance in maritime infrastructure.

H1 (Alternative Hypothesis): Leadership principles significantly influence project performance in maritime infrastructure.



Statement	Mean	N	Std. Deviation	T-Statistic	df	Sig. (2-tailed)
My team motivated and confident at work.	8.792	34	.000	1.457	1.12	1.79
Leaders in my organization lead by example and set high standards.	18.278	34	.000	1.857	1.65	2.08
My leaders help the team solve problems and make better decisions.	12.766	34	.000	1.514	1.27	1.76
Leaders communicate clearly and keep the team updated.	15.253	34	.000	1.914	1.66	2.17
Good leadership has helped my team finish projects successfully and on time.	13.117	34	.000	1.457	1.23	1.68
Leaders encourage us to accept and adapt to new technologies.	19.147	34	.000	1.886	1.69	2.09
My leaders support the team during major changes at work.	11.931	34	.000	1.629	1.35	1.91
When new systems are introduced, leaders ensure proper training and guidance.	17.514	34	.000	1.829	1.62	2.04
Leaders make sure everyone in the team works well together.	15.689	34	.000	1.743	1.52	1.97
Good leadership reduces stress and creates a supportive work environment.	15.289	34	.000	1.571	1.36	1.78
Leaders think about long-term success and sustainability in projects.	14.718	34	.000	1.743	1.50	1.98
Strong leadership improves trust and cooperation between different stakeholders.	13.179	34	.000	1.629	1.38	1.88

Result

The statistical analysis again showed a **p-value of 0.000**, which is less than the significance level of **0.05**. As a result, the **null hypothesis is rejected and the alternative hypothesis is accepted**.

This finding indicates that leadership principles such as clear communication, strategic planning, employee motivation, and technological support have a strong impact on the performance of maritime projects. Many respondents agreed that effective leadership helps improve coordination among employees, enhances productivity, and supports the successful completion of projects in ports and terminals.

Therefore, the second objective of the study is also achieved, showing that leadership principles play a significant role in improving project performance in maritime infrastructure.

Potential findings:

Vision over Machines: We anticipate that the most important factor for the success of projects will not be better machines, but "Transformational Leaders" that make the people feel like they're building the future of India, not moving containers.

The Cost of Silence: Based on the Anderson & Walsh study, we anticipate that we will prove that "Communication Gaps" are the silent killers of port efficiency. A good leader who can talk clearly and honestly is the most valuable asset on a construction site.

Recommendations:

The "Green & Human" Initiative:

To be able to convince everyone of the importance of making our ports "Green Ports," we need leaders who can inspire and facilitate this. We urge the government to provide "Green Leadership" training. Make them learn how to manage waste in order to enhance the overall cleanliness of the area so that health is also maintained along with the safety.

Leadership Training (The Practical Approach):

We shouldn't expect busy port engineers to go back to school for a degree. Once a quarter, the project leaders would attend a 2-day workshop on "Conflict Resolution" and "Managing Port Delays." This is the practical approach that does not remove them from their busy schedules.

Mentorship as a Performance Goal:

In many Indian organizations, managers at the top are too busy to actually teach. However, in order to make mentorship effective, it is not an option. Instead, the manager's bonus or promotion at the end of the year would partly depend on the performance of his junior employees. If "teaching" is actually linked to his performance, he would spend more time mentoring his employees.

Conclusion

The above analysis of the objectives and hypotheses reveals that the leadership plays a significant role in the success of maritime infrastructure projects. The results obtained from the statistical tests confirm that the leadership practices and principles have a significant effect on the development of the organization in the maritime terminals and ports.

The results obtained from the study reveal that the leaders help in the development of the organization in terms of improved communication, team development, and decision-making. They help in the development of the organization in terms of innovation and technology adoption, which is required for the development of maritime infrastructure.

Since the significance values obtained from the statistical tests are less than 0.05, the study confirms that the data obtained from the questionnaire is valid and reliable, and the research objectives have been successfully achieved.

Practical Suggestions

How Leaders can improve their leadership practices to ensure more effective outcomes from the employees.

Turn Experts into Mentors: Every port should have a "Passing the Torch" program. Instead of simply doing their job, senior managers should be rewarded for spending one hour a week mentoring a junior member of the team. This creates a human "safety net" for the organization.

Safe-to-Fail Digital Spaces: To assist with Objective 3: Tech Adoption, instead of simply launching a new technology, a "System" should be created where people can play with the new technology, make mistakes, and learn without fear of being fired.

The "One-Team" Huddle: Because of the number of organizations involved in the logistics process, a weekly "Community Huddles" meeting should be held. The logistics of getting the

truck driver, crane operator, and office manager in a room for 10 minutes solves more problems than a hundred emails.

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Risk Management and Role of Marine Insurance in International Shipping

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Abstract

The marine transportation connects the globe for international trade. Approximately 80 % by volume and 70 % by value goods are transported by sea. For vessels there is a hull and machinery insurance and P & I cover for liability. For cargo there is marine cargo insurance, a risk management tool to get financial protection. The objectives of the study are marine accidents related to cargo loss and cargo insurance, and to study the major trade routes and major accidents happening on these routes, cargo loss and insurance claims received. The second objective is to study the reasons behind cargo claim rejections for the practical case studies. The third objective of the study is the practical challenge in marine cargo insurance for which data is collected from importers, exporters, freight forwarders, ship owners/ operators.

Keywords: Cargo insurance, Risk management, Claim Rejection, Marine Accidents

Introduction

If there is a risk of loss from marine adventure or maritime peril the marine insurance policy provides compensation of the financial losses. The first world war, Second world war, container revolution, Piracy etc. these are the risks during sea transportation. To cover this kind of risk, cargo owners and ship owners take insurance to get protected from the financial losses. The maritime industry is a multimillion dollar industry. If any stakeholder like ship builder, ship-owner, cargo owner/ shipper, freight forwarder etc. wants to start their own business it will demand huge investment. Huge investment means there is a high probability of loss of money. In order to get protected from those financial losses, marine insurance becomes very important. Marine insurance is the oldest part of the insurance industry. Maritime business is the global business so as marine insurance is also a part of ancillary business of maritime and it is also a global business. (MRS Fatima Diana, 2022). With the birth of a human being there are several elements of the risk with which he is surrounded, newly born human beings have no expertise with the kind of risk associated with him/her. Risk is the complementary parcel of human beings. Risk is always there like a shadow of a human. Risk is faced by any person at individual level and business level. So insurance can provide protection against risk. Risk is the probability of adverse outcomes. Risk can be divided into two parts. Speculative risk refers to gambling. Another is there of probability i.e. gain or loss. Either risk taker can gain anything from that activity or he/she will lose from that activity. In business there are five different types of risks: strategic risk, financial risk, operational risk, compliance risk and other risks. (Syed Ahmed Salman, 2014) Marine insurance domain is very wide so there are various categories and various types of marine insurance policies. The types of marine insurance and category through which it gets insured, covers the benefits for the policy holder. It depends upon the client's business nature and scope and risk. Insurance takers can opt for the best policy according to their business nature, scope and risk. Ship owners can take insurance to protect their financial interest like Hull and Machinery policy, protection and indemnity cover, liability insurance, freight insurance. The shipper or cargo owner can take marine cargo insurance and goods in transit insurance. There are various marine insurance policies that are helpful to protect

against losses like named policies, single vessel and fleet policies, construction policy, blanket policy, port risk policy, wager policy, special hazard policy, composite policy, block policy, currency policy, proof of interest policy, special declaration policy, annual policy, inland transit cargo policy, inland vessel policy, free onboard policy, sailing vessel policy, package policy, Indian coast ports policy etc. (Chhote Lal Yadav, 2015). For the past hundreds years ship owners have been taking insurance to minimize the losses by taking different types of insurance policies. Ship-owners pay insurance premium when any unfortunate event occurs ship owner or policy holder claim the loss amount from the respective insurance company. Insurers use different methods for calculation of premium mostly the calculation of premium is based on statistical analysis using big data. Big data is helpful for ordinary maritime risk but it may not give reliable results for fully automated or remote control ships. The marine cargo insurance market is the largest commercial line of marine insurance business measured by insurance premium income. As per a report by International Union of Marine Insurance (IUMI) , various companies are bearing losses in insurance business due to high expenses ratio. When automated vessels are introduced in the market there is a challenge of data. There is no sufficient data available to identify the risk. When risk is not determined then there is also a challenge to identify the premium and calculate the premium. In autonomous vessels it is also called unmanned vessel so the technology is used more than a manned vessel. So if loss has happened in a vessel the expenses are higher than manned vessels. So that insurance premium is higher than the traditional vessel. After a few years after getting the data the insurance premium will go down. (Alop A., 2023) Insurance industry is the non-banking financial institution which plays an important role in protecting the financial losses of business. In the insurance industry there is a category of general insurance which bears risk of loss from insured objects against the premium. Marine cargo insurance is the insurance product that guarantees losses due to damage or losses in transit while traveling by sea. (C Santoso et. al, 2023).

Literature Review

Understanding marine insurance concepts

The discussion concerning the concept of marine insurance begins with classification of the risks as a more contemporary approach to begin the debate. The research employed both conceptual and descriptive approaches to categorize the concept of marine insurance into the three parts hull insurance, freight insurance, and liability insurance. The research was in agreement that insurance is a tool. Since the research was dependent on classification, the research did not give any information about the emerging challenges of the concept of marine insurance in the context of new technologies such as autonomous vessels, as said by the author (Alop, 2023). The following stage of the classification of risks research then introduces the deeper into the character of maritime risk by the application of the law principles. The research suggests the concept of perils of the sea and the concept of proximate cause. The study concludes that claims can be made through the accident and natural forces of the sea. Although this study is significant in understanding maritime risk, it is weak because it is old and has failed to consider new risks in operations such as technology and cyber failures (Everett V. Abbot, 1893). The history of marine insurance found the history of marine insurance as an insurance as a service. The paper focuses on the development of insurance markets as in the case of Lloyds and how the exchange of information contributes to the assessment of risks. According to the study findings, marine insurance as any type of insurance service developed alongside international trade, which preconditioned its belonging to the system of global trade. Nevertheless, the research did not determine the evolutionary relationship in the 21st century of the globalized and digitalized world (Huebner, 1905). The transformation between history and a modernized world, a descriptive analytical approach to explain and examine the definition, risks, and category of losses in marine insurance. The paper clearly distinguishes between overall and conditional losses, which

offers a realistic overview on the development of risks in transit. The paper once again establishes that marine insurance is directly connected to shipping operations phases (Meril, 2022).

Legal and practical challenges

The changing and increasing complicated risks, the concept of seaworthiness is reconsidered. Redefined seaworthiness is conceptual and legal in nature, dynamic and ever-evolving through the actions of technology and human factors. The research found that the seaworthiness is no longer dependent on the physical condition of the ship but also on human and technological factors. This developmental definition of seaworthiness is however not all objective in measuring seaworthiness, particularly in autonomous shipping. (Padovan, 2023) To bring these ideas to the subject of law undertook a doctrinal introduction to marine insurance law. The paper tells the major terms such as insurable interest and utmost good faith besides defining their legal foundations. The research results indicate that the marine insurance law aims at supporting the foundation of all decisions. The paper fails to discuss the discrepancies in international legal practice. It is a weakness on the global standardization level. (Pavliha, 2010) The analysis of causation in marine insurance in a legal approach of reading the law will be in extension to the discussion of proximate cause that was addressed before. The case study shows that contemporary courts struggle with determining the Dominant Cause in cases where there are several causes of an action. It is however successful in diagnosing the problem but it does not offer a scheme of resolution of the same, which is a big blank. (Rejwerska, 2024) To present all ideas, consider the fundamentals of marine insurance dealing with a conceptual study. The analysis refers to the fundamental principles of indemnity, subrogation and utmost good faith among others. The research also refers to the fact that there are certain principles that are becoming outdated in reference to the technological and commercial trends. The major gap that has been identified is the industry's experts unable to change and bring the traditional principles to be aligned to the current maritime practice. (Paul, 2021) Going further author applies the descriptive form of analysis to examine the functioning of marine insurance in the international trade frameworks. The results have shown that insurance provides a stabilizing factor, the legal compliance and commercial operations are connected together by the insurance. The analysis has left out the full impact of changing international trade patterns, including the use of digital documentation, on the traditional legal systems, which leaves the gap in which the need to research should be addressed in the future. (Stopford, 2009) Author uses a comparative approach to the law to examine the liability of the carriers in international conventions. The paper concludes that there are vast differences in the jurisdictions regarding the liability regimes, which argues in favor of complexity in settling claims. Although it contains good legal reasoning, it lacks in harmony mechanisms, and leaves a void in the attainment of consistency in global maritime law. (Tetley, 2008) Author applies a doctrinal legal paradigm of scrutinizing the obligation of utmost good faith, especially of disclosure. The paper concludes that insurance contracts can be annulled when the material facts are not disclosed. Although it is legally clear, the research fails to provide the way in which digital data sharing can decrease the non-disclosure problems, which is a gap in integrating technology. (Merkin, 2014). The article explores a particular legal contractual problem through a case-based legal analysis. According to the research, mistakes in the declaration of the sailing date may reject the coverage, causing claims disputes. The study fails to investigate automated verification mechanisms, which is a weakness in the prevention of such mistakes using technology. (Howard, 2012) Histories of modern marine insurance would be impossible to complete without reference to the increase in coverage past the traditional perils and study reveals this development by doctrinal examination of the Inchmaree Clause. The analysis clarifies that under this clause, they can be covered by risks like machinery breakdown and crew negligence which were not covered in the past under perils of the sea. Its relevance is indicated in its findings to the alignment of insurance to

technological advancements in shipping. There is a gap in the study though as it does not look at the consistency on the interpretation of this clause across jurisdictions casting doubts on the uniformity in the application of this clause in international trade. (Gilman, 2017)

Types of insurance policy

The debate on the categories of marine insurance usually starts with the risks that require specific insurance. The paper focuses on such threats as piracy and the threats of war. Based on a descriptive research design, the paper describes how the hull insurance is ineffective in meeting war related risks resulting in the introduction of the war risk insurance alongside kidnap and ransom (K&R) cover. The results indicate that current maritime activities need multi-layered insurance coverage owing to the rising level of geopolitical instability. The analysis fails to estimate the prices of premiums or determine the economic cost of such special insurance, which creates a data gap on the economic trade-offs. (King, 2008) In their study on the impact of piracy on insurance decisions selected a qualitative and descriptive approach in the investigation of the effects of piracy on the insurance decisions. The paper provides four key types of insurance, including war risk, K&R, cargo, and hull, and shows the ways ship-owners use them in combination with each other. It concludes that piracy adds a lot of operational cost which is the insurance premiums and security costs. Regardless of these observations, the research does not contain any statistics modeling of the probability of risk, which is a gap in predictive insurance planning. (Bendekovic & Vuletic, 2013) After determining the need of various forms of insurance, the discussion is to the policy structures by analyzing the different forms of insurance using a historical and doctrinal approach. The research proposes a broad category of marine insurances such as vessel and cargo, freight and special marine insurance such as tug and yacht insurance. The results show the flexibility of marine insurance contracts through time. The paper is still based on historical practice and does not consider how these types of policies have undergone changes in consideration of the present shipping complexities, which leaves a gap in modern applicability. (Huebner, 1905) Continuing on the diversity of policies offers a more organized description based on descriptive analysis. The research sub classifies policies as floating, valued, unvalued, and named policies with the researcher giving explanations of how they are put into practice in trade. The results imply that these types of policies are flexible with regard to shipment frequency and value certainty. The research fails to measure the effectiveness or the performance of these policies in settling claims, which forms a gap between theoretical classification and actual performance. (Yadav, 2015) Diversifying of marine trade also brings a new perspective, who concentrates on refrigerated cargo. The analysis is based on a doctrinal and industry-specific approach to analysis of the insurance clauses that target specifically temperature sensitive goods. The results indicate that the presence of human error and temperature changes is the core cause of claims, and special insurance is absolutely necessary. Although it is practically relevant, quantitative risk assessment models are not used in the study creating a gap in predicting and minimizing such losses. (Klopitt, 2022) Lastly reduces the scope to hull and machinery insurance with the help of a legal and conceptual approach. The paper focuses on insurers in the capacity of covering physical and operational risks of ship owners. It concludes that such principles as indemnity and insurable interest play a key role in settlement of claims. The research overlooks new risks like mechanical problems through automation or cyber-related losses, which is the sign of a gap in the adaptation of the traditional hull insurance to new challenges (Hartanto, 2020)

Economic impact of insurance

The economic purpose of marine insurance is most used when we consider it as affecting investment choices, and has a strong introduction. The present study uses a quantitative research approach to examine the impact of the availability of insurance on investment in the shipping sector in Nigeria. The results illustrate that there is a positive

correlation, i.e. the more insurance coverage is available, and the more investment is made by reducing the risks. The research also reveals a very important gap: even with all of its significance, the insurance penetration is still low, which does not allow its potential to stimulate economic growth in the maritime sector to the full extent. (Okparaka, 2022) Making a shift between developing economies to a historical European background, used the archival and historical analysis to determine the evolution of marine insurance markets in Spain. The paper also reveals the role of organized insurance markets in such cities as Cadiz that helped the maritime trade to be easy as they underwent risks sharing and financial security. It also points out how the wars and the economic shocks caused market instability and even bankruptcies. Although the research offers historical information, it falls short of relating such lessons to the global insurance systems and how in the contemporary world, markets can respond to such shocks in a better way. (Pons, 2021) With the change of the discussion to the measure of economic impact the more technical approach is presented by a quantitative modeling of the Monetary Value at Risk (MVR). The study approximates the exposure to maritime risks and insurance requirements through the analysis of large volumes of vessels in the world. The results demonstrate that the insurable value is massive and underinsurance remains an old and ongoing problem. But the study lacks micro-level understanding of the responses of individual firms or ship-owners to these risk valuations and thus there is a gap between the macro analysis and application of decision-making. (Knapp) Still in the economic discussion the author uses a statistical and comparative method to explore the correlation between cargo insurance increase and a number of economic variables like GDP. The research concludes that cargo coverage has been increasing at a higher rate of GDP, as well as, maritime trade, which implies its mounting significance in the economies. This implies that insurance is not a complementary service, but it is rather a catalyst to economic resilience. Nonetheless, causality, or the nature of the relationship between insurance growth and trade is not effectively examined in the study leaving a gap in the research to be filled in future. (Mitkov et al., 2021) Another historical aspect adopts an archival research as a method to analyze the transformation of insurance market structures in early America into external shock, particularly the war. The research concludes that the risks increased making individual underwriters no longer viable and corporate insurance organizations emerged which were better in terms of risk pooling and financial stability. This change underlines the flexibility of the insurance to economic pressures. The paper fails to compare these historical changes with the present day market structures, and there is an appreciation gap on how the modern systems can be developed in the case of similar crises. (Kingston, 2007)

Different aspects of marine insurance and tech in insurance

The topic of expanding the scope discusses how insurance is relevant to marine fisheries in a stochastic model. The paper has shown how insurance has the potential of stabilizing incomes and facilitating reduction of risky behavior among fishers and this leads to economic sustainability and conservation of resources. The evidence indicates that insurance has some potential to develop beyond risk transfer. Issues in implementation, particularly, inability to project risks as well as institutional support reveal a serious gap in the application of theory to practice. (Mumford et al., 2009) The marine insurance revolution is a process that is initiated not by technology itself, but by the talking with the user with the technology. This is the viewpoint assumed by the author who selected an empirical research approach, studying the customer awareness, satisfaction, and engagement with digital insurance platforms. The research concludes that despite the rise in availability of online processes and digital tools, customers continue to experience difficulties in finding out about policy specifications and having confidence with automated systems. This generates a very important point that technology is not sufficient to create efficiency until users become comfortable with it. The first key gap is the absence of easy to use online interfaces and the awareness initiatives because of minimal adoption of smart insurance usage. Pius and Sekar

(2025), Customer perception provides information on the demand side of the case, but the author turns to the supply side with the assistance of creating a technology-oriented insurance model. The study develops a system using a Design Science Research (DSR) approach that incorporates a premium prediction system, a Chabot based system, and product recommendations. A regression model is used to forecast the premium rates and the results show that there is a high degree of accuracy in risk assessment. This is an example of how artificial intelligence can increase the efficiency of the underwriting process and decision-making. The study lacks, however, on the real-life implementation issues like the availability of data, regulatory limitation, and acceptance of the model by the users that are not covered with the technical strength. (Santoso et al., 2023) Passing the discussion into reality, the author considers an available AI-based and big data-driven insurance platform and applies the case study approach. The paper outlines the mechanisms of the use of behavioral data, especially information on vessel tracking systems such as AIS, to develop dynamic risk profiles. The results indicate that the use of such data-driven models can increase risk prediction to a great extent and enable insurers to transition to behavior-based underwriting instead of the traditional fixed prices. This is a significant move in the right direction of having really smart insurance systems. The study includes dependency on high-quality data and complexity of integration, which are not fully discussed, leaving the gap in the comprehension of scalability and adoption in varying markets. (Timms et al., 2021) With increased interconnectedness of global trade, a quantitative risk assessment method in order to examine the risk of cargo accumulation a single catastrophic event will affect multiple shipments. The results say that ports, warehouses, and transshipment hubs form risk concentration areas, which may result in losses. Although the study successfully measures the problem, the dynamic mitigation of risks with any real-time information is not presented, so there is a gap in the adaptation to modern and fast-paced supply chains. (Cummins and Mahul, 2009)

Claim handling

The case into claim handling starts with the charter agreement where the author takes the approach of conceptual and legal analysis to study the incorporation of insurance clauses into charter party agreements. The analysis shows that uncertainties in contractual terms tend to be a source of conflict between the ship-owners and charterers and especially on the issue of liability apportionment. Although the paper has been successful in raising the issue of contractual complexities, it fails to provide a gap in the provision of standardized frameworks that may reduce such disagreements in reality. Rodrigue (2020) Entering further into the claims process, Author uses the qualitative research approach, examining the case-based evidence to find the barriers to the claim settlement. The results indicate that the main obstacles are delays, documentation deficiency, policy terms misinterpretation. The research fails to measure the economic cost of such delays, which is why it does not provide a complete picture of the economic effects of ineffective claim processing. (Soyer, 2019) Author focuses on the technical foundation of insurance contracts by a doctrinal approach to law. The paper describes how warranties and policy terms put requirements on effectiveness of claims. It concludes that small violations may result in the denial of claims, which underlines the strictness of the marine insurance law. The characteristic of modern day commercial realities that are not entirely represented in conventional warranty enforcement. Bennett (2018) Author focus on seaworthiness in terms of a case of law analysis approach. The research discovers that insurance claims may reject to be valid and liability transferred in case of neglect in seaworthiness. The seaworthiness as understood is relative and no measurable standards are given in the study and perhaps this is where the practical application fails. Wilson (2010) Author discusses the insurable interest in the context of theoretical analysis of the law. The results highlight that invalid insurable interest is a key factor to ensure that a claim is not enforced due to speculative insurance practices. The research fails to cover the current complexities like multi party logistics chain and thus there

is a disparity between the concept adaptation to modern shipping practices. (Clarke, 2013) Author takes a process of analytical approach in order to describe claim settlement stages. The paper concludes that structured processes enhance transparency and efficiency in the process of handling claims. It fails to incorporate digital solutions in these processes, which would demonstrate an element of modernization. (Dunt, 2016). Author introduced another contemporary point of view with the help of a quantitative and process optimization methodology. The research concludes that a better practice of documentation is associated with a higher level of efficiency of claim settlements and decrease in settlement disputes. The paper does not go further than creating completely automated systems, which leaves a vacuum to complete end-to-end processing of claims that is digital. (Kumar and Singh, 2021). Changing the topic of clauses to practice, Author uses a descriptive and analytical approach to place marine insurance as the component of the commercial activity. The paper concludes that insurance is no longer a passive risk-transfer mechanism but an active element in the trade contracting, financing, and logistics decision-making processes. This view has been used to highlight the fact that insurance is part of business strategy. The study does not delve into the manner in which smaller companies or emerging economies can incorporate insurance into their systems and this creates a loophole in inclusivity and availability. (Hodges, 2015) The story thereafter turns to the environmental forces, in which the author adopts qualitative and trend analysis to take a look at how climate change is transforming marine insurance. The research concludes that the frequency and severity of claims are rising because of increase in sea levels, extreme weather events, and unpredictable ocean conditions. This compels the insurers to rethink their pricing and coverage policies. Nevertheless, the study does not provide any definite predictive models as one of the gaps in the long-term risk forecasting and adaptation measures. (Lambert, 2020) The concept of operational transformation is highlighted by presenting a case based analysis of it, but the primary emphasis is put on containerization. The researchers conclude that even though containerization has made supply chains efficient and less expensive, it has also created some new risks including undeclared cargo, fire hazards, and loss of visibility. This two fold influence brings into focus the changing aspect of risk in contemporary shipping. The loophole is that there are no sophisticated surveillance mechanisms and laws in place to deal with these arising risks. (Notteboom, 2016)

Objectives

1. To study maritime accidents related to cargo loss and cargo insurance.
To know how much cargo loss is happening if any marine accident happened on any global maritime trade route. And what is the financial value for that loss?
2. To study the reasons for cargo claim rejection in marine transportation.
To study the practical reasons for cargo claim rejection. So if any shipper makes any mistake in transportation and their claim gets rejected from their experience, other shippers can improve their mistake and protect themselves from financial losses.
3. To study different types of challenges faced in marine cargo insurance.
By filling the questionnaire from the industry stakeholders to know the impact on marine cargo insurance if any technical issue arises in the vessel.
4. To study the recent developments in marine cargo insurance in India and Europe.
To know what improvements India can do in the marine insurance segment as compared to the European market.

Research Methodology

Research Design

Exploratory research design: Investigation of poorly defined problems with the aim of gathering knowledge, identifying trends for further research is known as exploratory research design. The study aims to find out accidents that happened on the major maritime trade route. To achieve the first objective to study the maritime accident related to cargo loss and cargo insurance.

Descriptive research design: Recent development in marine cargo insurance was used to achieve the fourth objective of what development happened in India and Europe.

Sources of data

Primary Data: Primary data collected from cargo surveyor, exporter, importer, ship owner, charterer, marine insurance professional through questionnaire to achieve third objective to study different types of challenges faced in marine cargo insurance.

Secondary Data: Secondary data collected from Insurance Company's website, Journal, Articles, Case studies etc. to achieve first, second and fourth objectives.

Target population

Element: Insurance Companies, Shipping and Logistics companies, Cargo owner

Sampling unit: Cargo surveyor, Insurance managers, Insurance agents, exporter, importer

Extent: India

Time: July 2025 to April 2026

Sampling Technique:

Convenience Sampling: It is convenient to gather data from cargo surveyor, insurance companies for researchers.

Snowball Sampling: It is difficult to reach each and every expert so experts can forward Google Form and refer.

Judgment Sampling: To understand development in marine cargo insurance For research have to find a credible source for secondary data.

Sample size:

30-40 respondents for objective three

Discussion

1. To study maritime accidents related to cargo loss and cargo insurance.

Major routes to transport the goods in world

1. Trans Pacific Ocean Trade Route
2. Asia Europe Route
3. Transatlantic Shipping Route
4. South America Europe Trade Route
5. Intra-Asia Route
6. Panama Canal Route
7. Asia Middle East

8. Europe UK Trade Route
9. Russia to Europe Trade Route
10. Red sea Route

1. Trans Pacific Ocean Trade Route

It is the world's busiest route. It connects Asia and North America across the Pacific Ocean. It also includes the South China Sea and the Taiwan Strait. In this route approximately in 2022, 28 million TEU trade happened.

Major exporting countries from Asia

China, Japan, South Korea, Taiwan, Vietnam, Thailand, Malaysia, Singapore, Indonesia, Philippines

North America Importing Countries

United States, Canada, Mexico



Case

On 30 November 2020 ONE Apus was a 14,000 TEU container vessel sailing from Yantian Shenzhen to Long Beach, California during the voyage it encountered severe weather conditions and heavy rolling. It caused the loss of approximately 1816 containers including 64 with dangerous goods. The ship arrived at Kobe, Japan on 8th December when it offloaded 1000 damaged containers and resumed its voyage on 16 March 2021.

Source [Wikipedia](#)

2. Asia Europe Route

It is the world's busiest container trade route. This route includes the Suez Canal which is 193 km in length. The Suez Canal connects the Mediterranean Sea and Red Sea. If the

canal block or close due to any reason the every ship have to take detour and have to go Southern tip of Africa via Cape of Good Hope but it increases the transit time and shipping cost.



Case

On 21 March 2006 MV Hyundai Fortune container ship owned by Kosmo SVCS Inc. and flagged from Panama enroute from ports in China and Singapore through the Gulf of Aden about 60 miles to the south of the coast of Yemen. She was sailing west towards the Suez Canal on the way to the port of Europe. During the voyage an explosion from unknown origin occurred below the deck, aft of the accommodation. It caused 60 to 90 containers to fall in the ocean. The explosion caused fire on the ship and it spread through the stern of the ship including accommodation and container stack. After this incident 27 crew members abandoned the ship. The combined cost of ship and cargo is \$800 million.

Source [Wikipedia](#)

3. Transatlantic Shipping Route

It connects North America with Europe across the Atlantic Ocean. It connects with the English Channel which distinguishes the U.K. and Europe. And links the North Sea and Atlantic Ocean. The narrow part of the channel is the Dover Strait; around 400 vessels passes daily.



Case

Felicity Ace was a 60,000 tons roll on/roll off car/truck vessel owned and operated by Mitsui O.S.K. Lines of Japan and registered in Panama. On 10th February 2022 the vessel was sailing from Emden, Germany carrying 3965 Audi, Porsche, Lamborghini and Bentley. The cargo section caught fire on 16th February 2022 while crossing the North Atlantic heading for Davisville, Rhode Island. All 22 crew members were evacuated from the ship by the Portuguese Navy. The reason for the fire is the lithium ion batteries of electric cars ignited. The salvage operation was conducted. On 1st March, Felicity Ace was reported to have capsized and sank. After this accident Porsche lost 1,117 cars on the ship, Audi claimed a loss of 1,944 vehicles, Volkswagen lost 561, Bentley lost 189, and Lamborghini lost 85 cars. Analysts estimated the damage caused by the cargo loss to be between US\$334 million and US\$401 million.

Source **Wikipedia**

4. South America Europe Trade Route

It covers the Atlantic Ocean. It connects South American ports like Ports in Argentina, Chile and Brazil with European ports like Spain, United Kingdom, and Netherland, Portugal.



Case

MV Flame was a Panama flag bulk cargo vessel. On 12th August 2007 it departed from Europa point and sailed to Turkey carrying 27,000 tons of scrap metals and 750 tons of fuel oil. About one kilometer south of Europa point it ran into the stern of Torm Gertrude, a double hulled Danish petroleum tanker. After the collision the tanker proceeded towards Algeciras where it was secured with its cargo of 39,000 tons of fuel. New Flame took water on the bow side so that it got grounded nearby. Removal of vessel fuel initiated on 15th August. It was the first priority of the salvage operation to minimize the environmental impact of the collision. A total of 780 cubic meters of fuel had been removed from the vessel.

Source [Wikipedia](#)

5. Intra-Asia Route

It covers the Asia Pacific region. It connects the ports in East Asia including Japan, China, and South Korea with the Southeast Asia region like Vietnam, Malaysia, and Singapore. Textiles to electronics, machinery, raw materials, consumer goods and agricultural items are shipped via this route.



Case

On 5th May 2014 Zheng Xing 2 Chinese vessel with 12 crew carrying cement from Hebei to Haikou and MOL Motivator container ship registered in Marshall Island with 24 crew traveling from Hong Kong to Yantai both vessels collided with Po Toi Island and Chinese vessel sunk and all 12 crew member died. Poor visibility is reported as a reason for the accident. Heavy rain, lightning and thunderstorms cause problems with ship radar.

Source [Wikipedia](#)

6. Panama Canal Route

The Panama Canal links the Atlantic with the Pacific Ocean, reducing the sea voyage between the east and west parts of America. It is around 80 km long. The canal also functions as a major link for vessels sailing between ports of South America and North America, enabling the trade of cargo like grain, minerals and oil.



Case

Themis was a steam cargo ship built in 1911. On 7th September 1917 it sailed from Karachi with 11,000 tons wheat, 260 tons of St Johns bread and some other general cargo for Marseilles via Suez Canal. During this voyage 37 crew onboard. On 12th October 1917 it was about 20 nautical miles north of Cape Bon. The ship suddenly hit the torpedo on the starboard side. After this crew abundant the ship. It got sunk.

Source [Wikipedia](https://en.wikipedia.org/wiki/Themis_(ship))

7. Asia Middle East

In this route vessels sail from Asian ports of China, India or Southeast Asia to Middle Eastern ports including UAE, Oman and Saudi Arabia. Another route is Hormuz strait which is between the Persian Gulf and the Arabian Sea. The majority of oil and gas trade is occurring through this route.



Case

From November 2023 to September 2025 total 97 attacks happened on the vessel which we know as a red sea crisis. These attacks were made by the Houthis. According to the annual report of the world shipping council 576 containers were lost at sea in 2024. Which was increased from 221 containers lost in 2023.

Source [Wikipedia](#)

Marinelink

8. Europe UK Trade Route

It connects the southern coast of the UK and North France. The English Channel connects from the North Sea and the Atlantic Ocean enabling maritime trade between Europe and the UK. Over 500 ships pass every day. The Dover Harbor on the British side of the strait and the Harbor of Calais on the French side are the busiest harbor of the world.

Case

MV Tricolor was a Norway flag vessel. The capacity of the vessel was 50,000 tons. It was built in 1987. On 14 December 2002 the vessel was travelling from Zeebrugge, Belgium to Southampton, UK with 3000 cars. The vessel collided with the Kariba container vessel. After the collision Kariba could sail but Tricolor sank and was stuck in the English Channel. It is 17 nautical miles from the French exclusive economic zone.

Source [Wikipedia](#)

9. Russia to Europe Trade Route

The Danish Strait connects the North Sea and Baltic Sea and has three channels- the Great Belt, the Little Belt and the Oresund. Crude oil and petroleum is mainly transferred throughout this route. There are other routes like the Baltic Sea route which connects

Russian ports of St. Petersburg and Kaliningrad with the European ports like Rotterdam, Hamburg and Stockholm.



Case

On 29th March 2001 between Germany and Denmark the product tanker Baltic carrier collided with a bulk carrier in the Baltic Sea. The vessel didn't sink but 2700 tons of heavy fuel oil was lost in the Baltic Sea out of 30,000 tons of oil.

Source **ITOPF**

10. Red Sea Route

The Red Sea lies between Africa's north east coast and the Arabian Peninsula. It connects to the Mediterranean Sea via the Suez Canal and the Indian Ocean via the Bab el Mandeb Strait. The Red Sea Route is used for shipping cargo from Europe and the Mediterranean region to Asia, bypassing the Suez Canal when needed. It also enables trade between the Middle East, East Africa, and South Asia.



Case

The Houthi attacked on cargo vessel Eternity C and it sank in the red sea. The incident occurred in July 2025 and Houthi forced crew members to abandon the vessel.

Source **Reuters**

Source **Marineinsight**

The deadliest shipping container routes

1. The Horn of Africa: The Pirate infested passage

The coast of Somalia, Gulf of Aden and Horn of Africa are influenced by maritime piracy. In this critical corridor container ships are travelling between Europe, Asia and the Middle East and it is the hotspot for pirate activity. Somali pirates target a wide range of vessels like container ships, fishing boats, tanker vessels etc. and they are engaging in hijacking, thefts and ransome demand. In 2009 hijackers hijacked the U.S. flag container vessel Maersk Alabama. In late 2000s and early 2010s the piracy peaked in the Horn of Africa.

How piracy happens?

Pirates use small and fast boats to board larger vessels taking hostages and demand multimillion dollars as a ransom. So that in this region the shipping cost is high due to insurance premiums and security measures.

How to overcome this issue?

To overcome this issue in this region International naval patrols, including this from NATO, the EU etc. deployed to the region and also arm guard on ships onboard to enhance the security protocols. These steps could help to reduce the successful attack on vessels.



2. Strait of Malacca

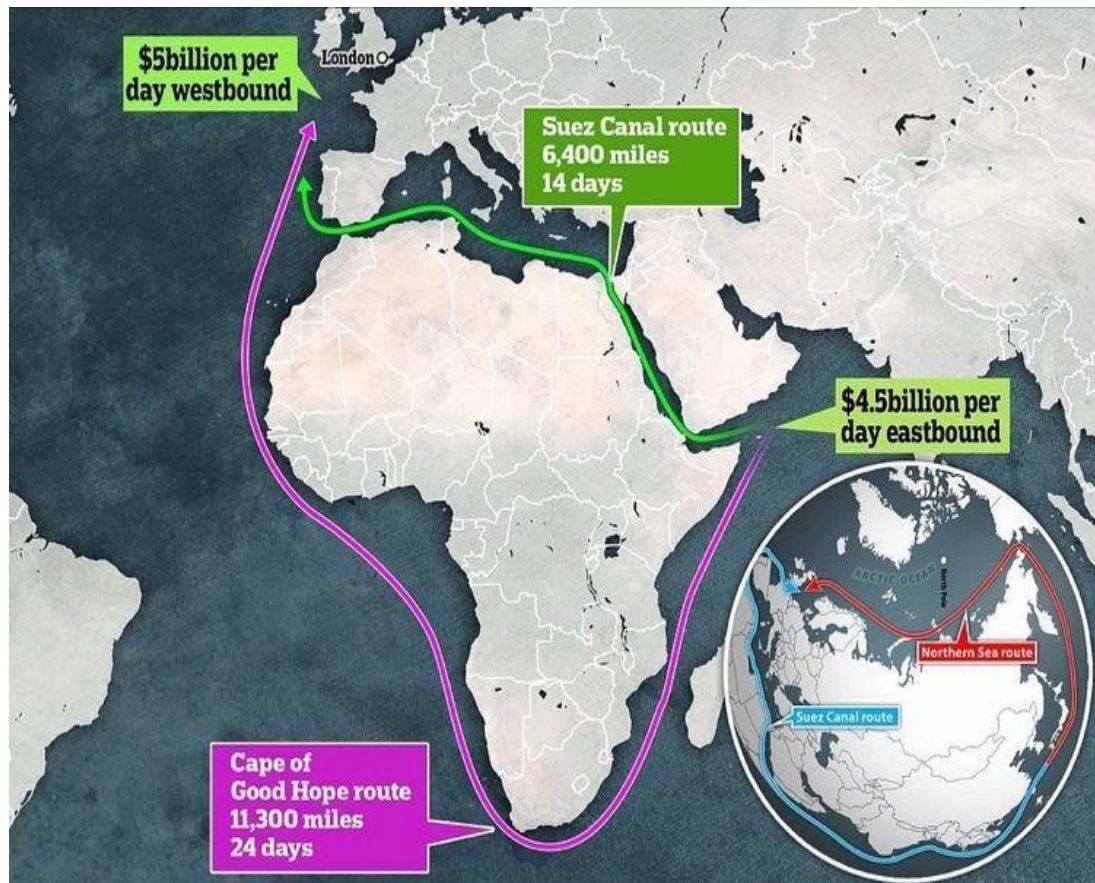
The Strait of Malacca is the narrow region which connects the Indian ocean and Pacific ocean, and is one of the busiest routes in the world. It serves container traffic between Asia, Europe and the Middle East with an estimated 60,000 vessels annually. The primary hazard of the Strait of Malacca is their geography; at the narrowest point it is just 1.7 miles wide, it creates bottlenecks which increase the risk of collision and grounding. In this region the collision happens between container ships and oil tankers due to the oil spill and it damages the environment and trade disruption. In this region the piracy risk is also there so that the Malaysian, Indonesian and Singapore governments collaborated and implemented joint

patrols and surveillance systems. Also shipping companies rely on radar and AIS to prevent the accident.



3. The Suez Canal

It connects the Mediterranean Sea and the Red Sea. It is very important for global trade. It can avoid the lengthy route of the Cape of Good Hope. It can reduce the transit time and fuel cost. It connects Europe and Asia. It is a very narrow channel and it contains huge traffic so it becomes deadliest in nature. The Suez Canal is 205 meters wide at its narrowest point. Its length is 120 miles. It handles 10% of global trade. A single error can disrupt the traffic and supply chain. Here there is a risk of collision, grounding. In 2021 Icona-class container ship the Ever Given ran grounded and blocked the canal for six days. It caused delays to other ships and millions of dollars occurred. In the Suez Canal the risk of accidents are very high because of poor visibility, strong wind and human error. To mitigate this risk the canal authority invested in infrastructure improvement to widening section of waterways.

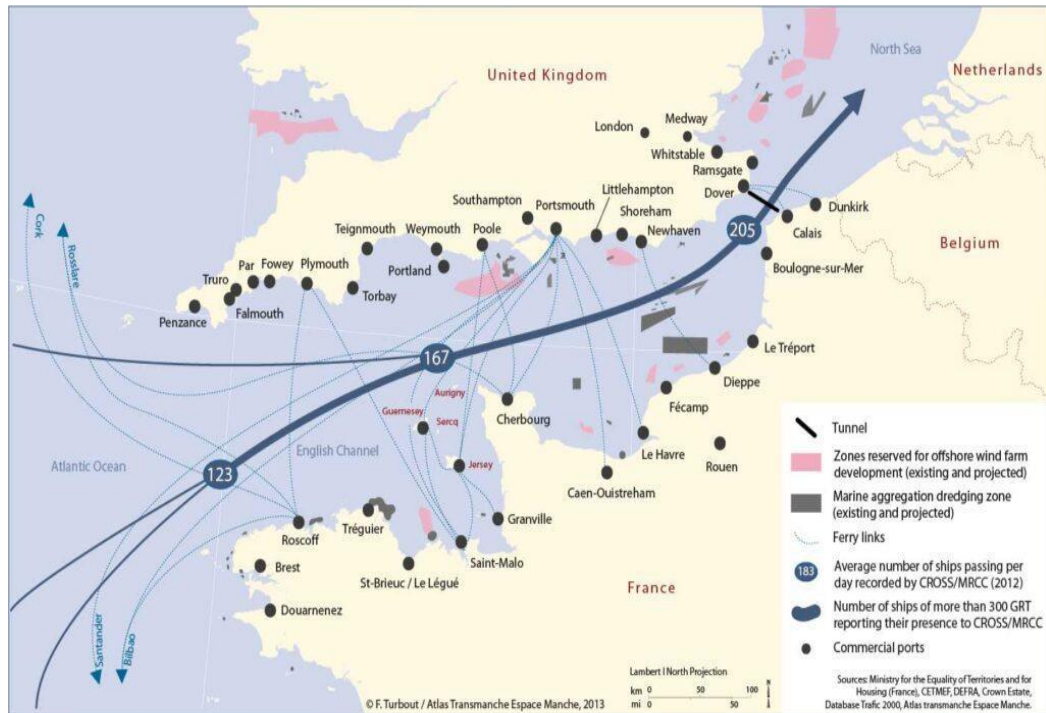


4. The English Channel

The English Channel Dover strait is the busiest route for container ships, ferries and fishing boats. It separates the United Kingdom from continental Europe. The trade happens between this route, Northern Europe and the rest of the world. The Dover strait is the narrowest space just 21 miles wide so that probability of collision is very high. This channel's strong tidal current, frequent storms create navigation difficulties. In 2002 MV Tricolor the car carrier collided with another vessel and it sank resulting in the loss of ship and cargo.

What steps they took to prevent

To manage the risk Dover strait is governed by a traffic separation scheme (TSS) that organizes the vessel traffic into designated lanes to prevent collisions.



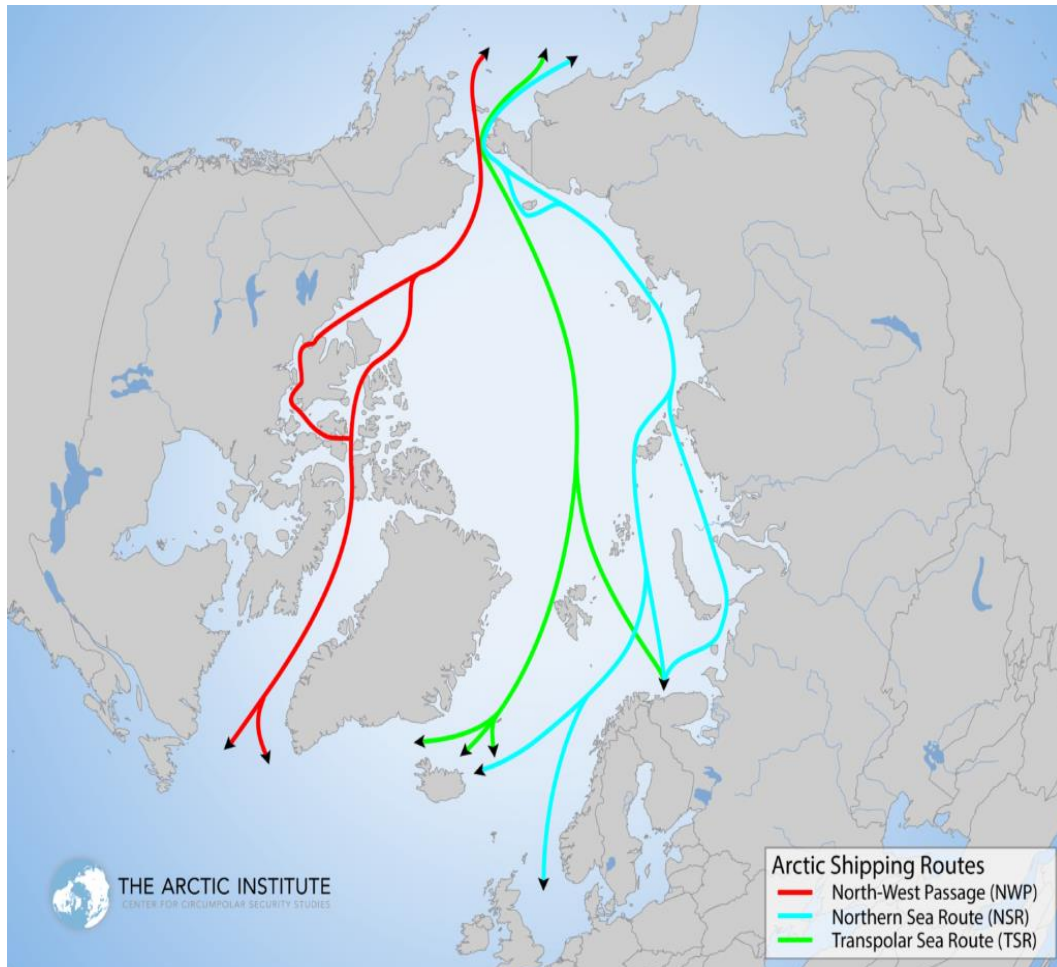
5. The Gulf of Guinea

The Gulf of Guinea is off the coast of Nigeria. In this route particularly the container ship is not transiting. This route is mainly for oil and gas transportation. In this region the pirates attack the ship for kidnapping the crew members and demand the ransom. They are not targeting the cargo.



6. The Arctic Routes

Due to climate change, the Arctic ice is melting so that new shipping routes are emerging. It provides shortcuts in Asia, Europe and North America trade. The hazards for these routes are icebergs, extreme cold, unpredictable weather etc. Even with melted ice floating ice creates threats to the vessel like hull damage or stranding.



Source **Containerlift**

Why is this important?

This objective is crucial because international maritime trade routes manage a lot of cargo and are vulnerable to a number of dangers, including bad weather, collisions, piracy, fire, and navigational hazards. The case studies, like the ONE Apus container loss and Felicity Ace sinking, demonstrate how accidents on important routes can result in substantial cargo damage and monetary losses. The research aids in understanding the primary causes of cargo loss and how they affect marine cargo insurance claims through investigating these incidents. This is crucial for enhancing risk management procedures, bolstering maritime transportation safety procedures, and ensuring that marine cargo insurance adequately shields cargo owners from monetary losses.

2. To study the Reason behind cargo claim rejection in marine transportation.

1. Non-disclosure of material information

The major reason for marine cargo claim rejection is not disclosing the material information by the insured. Material information includes the nature of cargo, its value, mode of transportation, and intended route. If the insured fails to provide this information, the claim will be rejected. So when the cargo owner takes the insurance policy they have to be careful about these things.

2. **Insufficient packaging**

If the packaging of the cargo is not export worthy and cargo got damaged during transportation then insurance claims may be rejected. Because the cause of damage is improper packaging. Due to improper packing the cargo gets damaged.

3. **Delayed reporting**

Delayed reporting causes the claim rejection. Delayed reporting can cause suspicion for fraud.

4. **Failure to mitigate the loss**

The insured have to mitigate the loss. If in the past the cargo was damaged due to water then the cargo owner should maintain the dry surface to prevent the loss.

5. **Exclusion in policy**

If the insured excludes any condition like act of war, and subsequently damage occurs because of war, in this condition the insurance claim might be rejected.

6. **Failure to comply with policy condition**

If the conditions are not satisfied then the marine cargo insurance is rejected.

7. **Fraudulent claim**

Receiving claim money cannot be for profit reasons, if any cargo owner claims the damage and cargo surveyor finds it as fraudulent the insurance claim will be rejected.

(Compiled based on some readings of policybazaar.com and other general observations)

Case 1

Consignor Name : M/s. EQUATE PETROCHEMICAL CO K.S.C.C.,
Equate Building, Plot No. 900011, Block 12,
Central Ahmadi PO Box 100, Ahmadi, Kuwait

Consignee Name : M/s. Shubhlakshmi Polyesters Ltd.
Sy. No. 126, Vill. Bhensali, Dahej, PCPIR, Bharuch

Name of underwriter : M/s. The New India Assurance Co. Ltd.

Mode of transport : By sea

Name of vessel : GS FUTURE VOY. 2118

Nature of content : Mono ethylene Glycol (MEG)
Net Quantity 500 MT,

Place of survey : At port premises where said cargo discharge,
I.e. Adani port, Hazira

Source of origin Kuwait

Discharge at Adani ports Hazira

MEG was purchased in 9 nos

As reported, the B/L qty. and Load port total quantity was of 15,751.553 MT. and accordingly vessel Ullage report- after loading in the vessel dated 31.12.2021, the total qty. was 15,751.553 MT.

When said vessel arrived at Adani port, they measured the quantity before discharge it, they observed the arrival quantity was 15,711.050 MT

Shortage 40.053 MT

And they started to transfer the cargo dated 08.01.2022 and they completed the discharge on dated 09.01.2022. But after discharging whole cargo, they observed the quantity received was of 15711.050 MT i.e. they received the shortage of 40.503 MT

The insured/consignee lodge the claim of Rest. 63,506/- for the shortage

The reason behind claim rejection is there is no evidence or there is no clue to cargo surveyor where this cargo went.

Source: Primary data from cargo surveyor

Case 2

<u>Transit from and to</u>	<u>Malaysia to Turkey</u>
<u>Cargo</u>	<u>Machinery</u>

A Malaysian company exported precision CNC machinery to Turkey. When machinery reached Turkey it showed severe impact damage on the base frame. The consignee reported damage after two weeks of delivery. For filing the cargo claim there is a window of three days only. The insurer refused to accept the claim because of late notice. The freight forwarder presented evidence from the shipment tracking system showing that the crate had been mishandled during inland transportation before custom clearance. In order to explain the delay in notice, the forwarder also produced email communication demonstrating that the consignee only became aware of the damage after uncreating the apparatus under expert supervision. After reviewing the documentation the insurer accepted the claim of 80 % (65000 USD). 20 % (16250 USD) claim got rejected stating that it can be repairable.

Case 3

Transit from and to	Penang to Jeddah
Cargo	Seafood

A refer container with frozen seafood shipped from Penang, Malaysia to Jeddah, Saudi Arabia. During transportation, the refer container malfunctioned for 18 hours. Due to this issue cargo quality degraded. The shipper has to prove that temperature fluctuation happens during transit not before loading. The freight forwarder coordinated with a refer service provider to retrieve data logger records shows that the cargo temperature remains stable before loading but it fluctuates during mid voyage. The data logger report and photos of damaged cargo submitted for marine cargo insurance claim. The insurers approved 90 % of the affected cargo value (48000 USD). 10 % of the claim got rejected. The coordination between shipping line and provision of temperature of records provides the success in claim otherwise it will reject the claim. 10 % claim got rejected because of inheriting vice.

Source: **TNS**

Case 4

The oil trading company insured petrochemical cargo under all risk open cover policy and it is reinsurance. When the vessel reached the port of discharge the insured cargo did not match the specification. The insured said that it is as per specification before the loading as per certification but during loading it got contaminated.

The possibility of contamination is not cleaning the pipeline, cargo tanks are not properly clean before loading, tank cleaning residue mix with cargo. As a result the cargo grade has been changed. The separation in temperature happens; it might be contaminated. The insurance company rejected the claim. Then it went into court. According to the court, the insured could only get compensation if the load-port inspection certificate accurately depicted the cargo's state when it was loaded onto the ship, which the evidence did not support.

The cargo claim is rejected because of lack of evidence of cargo when it is loaded, it is difficult to say the cargo contamination happens on loading port of shore tank or during the transit. Because cargo is transferred to the shore tank from the main tank.

Source: **HFW**

Case 5

In April 2023 the Advantage sweet vessel which was flagged from Marshall Islands and chartered by Chevron Corp. was sailing from Kuwait to Houston, Texas with the crude oil in Gulf of Oman. During the voyage in international waters Iranian naval forces seized the tanker and transferred the crude oil into the Iranian tanker because there was a geopolitical conflict with Iran and western countries.

There were three insurance companies involved Zurich American insurance, Liberty mutual insurance and Great American insurance. Chevron Corp. filed \$ 57 million insurance claim under marine cargo insurance and war risk cover but the claim was rejected. The insurance company stated that seizure of vessels will not be covered under war risk; it is excluded in the policy. It is not under either war risk nor cargo risk that's why the claim got rejected.

Source: **Energy world Middle East**

Africa, **Reuters.com**

The company has the goods of Rp 10 billion but they took insurance of Rp 5 billion. The damage occurred at Rp 2 billion. The insurance company paid Rp 1 billion because of underinsurance.

Source: **Ligaasuransi.com**

Case 6

Grass mats were shipped from Hong Kong to Long beach, USA. At the port of discharge the consignee found a few of the grass mats in wet condition. Which can't be sold in the market. The cargo owner filed a claim and stated that cargo was damaged just because of moisture and sea water ingress in the container during the voyage. A survey was conducted with the survey result telling that there is no evidence of container leakages or container damage. The surveyor said that the loss happened because of container sweat. Due to inadequate dryness before shipment and ventilation of mat it happened. The mat had been packed with moisture residue.

The insurer rejected the claim stating that it happened because of inheriting vice not by ingress of water in the container or carrier negligence.

The damage cargo amount is \$ 10, 00,000 and claim settle at \$ 30,000

Source: Alco.com

Case 7

Peacock plywood (P) Ltd vs. Oriental insurance co. Ltd.

The Indera Pertama vessel is sailing from Western Sabah, Malaysia to Kolkata, India with 474 logs of Rs 39, 90,122. The marine cargo insurance policy issued from Oriental insurance co. Ltd. With institute cargo clause C with extended warranty covering theft, pilferage, war, SRCC (strikes, riots and civil commotions) and non-delivery of single log. The vessel sailed on 16/02/1988 from Malaysia. During the voyage the engine problem arose so it was detained in Singapore and it became unseaworthy and cargo was unloaded at Singapore on 03/01/1989 and the vessel never reached Kolkata with that goods. The Peacock plywood sold the stock in Malaysia at the price of Rs 20,01,740.53. The total policy amount is 40 lakhs. Peacock plywood used in Supreme Court on Oriental insurance co. Ltd. During the trial the Supreme Court settled at 8.5 lakhs. 12 Lakhs is the loss of Peacock plywood.

Source: Casemine.com

3. To study the practical challenges faced in marine cargo insurance.

To achieve this objective I made a questionnaire which is attached in annexure.

I sent this questionnaire to the importer, exporter, freight forwarder, ship owner/ operator, marine insurance professional and others who are associated with marine cargo insurance.

1 N = 32

I want to know what is the correlation between technical issues in the vessel negatively impacting the cargo insurance claim.

SPSS Output

Variables

Q5 Technical issue in vessels negatively impacts cargo safety. (Independent variable)

Q6 Technical issue in the vessel negatively impacts insurance claims. (Dependent variable)

H0: (Null) There is no significant difference between technical issues in a vessel negatively impacts cargo safety and it negatively impacts insurance claims.

H1: (Alternative) There is a significant difference between technical issues in vessels negatively impacts cargo safety and it negatively impacts insurance claims.

N = 32

Table 1: SPSS Correlation output

Correlations

	Technical issue in vessel negatively impacts cargo safety	Technical issue in vessel negatively impacts insurance claim
Technical issue in vessel negatively impacts cargo safety	1	.240
		.187
N	32	32
Technical issue in vessel negatively impacts insurance claim	.240	1
	.187	
N	32	32

Correlation $r = 0.240$

P value = 0.187

Alpha value $\alpha = 0.05$

There is a positive correlation between technical issues in vessels negatively impacts cargo safety and it negatively impacts insurance claims.

The P value is 0.187 is $>$ alpha value α 0.05 so the null hypothesis accepted and alternate hypothesis rejected. That means if any technical issue arises in a vessel it will not negatively impact the insurance claim.

- 2 I want to know what is the correlation between the cargo hold condition and how its influence on marine cargo claim outcome.

Variables

Q14 Improper cargo hold condition affects cargo safety. (Independent variable)

Q15 Improper cargo hold conditions negatively influence marine cargo insurance claim outcome. (Dependent variable)

H0: (Null) There is no significant difference between improper cargo hold conditions affects the cargo safety and it influences the marine cargo insurance claim outcome.

H1: (Alternative) There is a significant difference between improper cargos hold conditions affects the cargo safety and it influences the marine cargo insurance claim outcome.

N = 32

Table 2: SPSS Correlation output

Correlations

	Improper cargo hold condition affects cargo safety	Improper cargo hold condition negatively influences marine cargo insurance claim outcome
Improper cargo hold condition affects cargo safety	1	.495**
	Sig. (2-tailed)	.004
	N	32
Improper cargo hold condition negatively influences marine cargo insurance claim outcome	.495**	1
	Sig. (2-tailed)	.004
	N	32

** . Correlation is significant at the 0.01 level (2-tailed).

Pearson correlation $r = 0.495$

P value = 0.004

Alpha value $\alpha 0.05$

There is positive correlation between improper cargo hold conditions affects the cargo safety and it influence the marine cargo insurance claim outcome.

The P value is $0.004 < \text{Alpha value } \alpha 0.05$ so the null hypothesis rejected and alternate hypothesis accepted. And $r = 0.495$ so it is a positive correlation. So we can say that improper cargo hold conditions affect the cargo safety and it will negatively affect the cargo claim outcome.

3 I want to know what the correlation between transparency about vessel condition impacts the marine cargo insurance claim.

Variables

Q10 Transparency about vessel condition improves claim acceptance

Q15 Improper cargo hold condition negatively influence marine cargo insurance claim outcome

H0: (Null) There is no significant difference between transparency about vessel condition improves claim acceptance and improper cargo hold condition negatively influence marine cargo insurance claim outcome

H1: (Alternate) There is a significant difference between transparency about vessel condition improves claim acceptance and improper cargo hold condition negatively influence marine cargo insurance claim outcome

N = 32

Table 3: SPSS Correlation output

Correlations

	Transparency about vessel condition improves claim acceptance	Improper cargo hold condition negatively influences marine cargo insurance claim outcome
Transparency about vessel condition improves claim acceptance	1	.416*
	Pearson Correlation	
	Sig. (2-tailed)	.018
N	32	32
Improper cargo hold condition negatively influences marine cargo insurance claim outcome	.416*	1
	Pearson Correlation	
	Sig. (2-tailed)	.018
N	32	32

*. Correlation is significant at the 0.05 level (2-tailed).

Correlation $r = 0.416$

P value 0.018

Alpha value $\alpha = 0.05$

There is a positive correlation between transparency about vessel condition improves claim acceptance and improper cargo hold condition negatively influence marine cargo insurance claim outcome

The P value is $0.018 < \text{Alpha value } \alpha 0.05$ so the null hypothesis rejected and alternate hypothesis accepted. And $r = 0.416$ so it is a positive correlation. So we can say that transparency about vessel condition affects the cargo claim negatively.

4 H0: (Null) There is no significant difference between ship owner risks like collision, grounding and structural failure.

H1: (Alternate) There is a significant difference between ship owner risks like collision, grounding and structural failure.

N = 32

Table 4: SPSS Nonparametric correlation output

Nonparametric Correlations

Correlations

		Collision risk of ship owner	Grounding and foundering risk of ship owner	Structural failure risk of ship owner
Spearman's rho	Collision risk of ship owner	Correlation Coefficient	1.000	.804**
		Sig. (2-tailed)	.	.000
		N	32	32
	Grounding and foundering risk of ship owner	Correlation Coefficient	.804**	1.000
		Sig. (2-tailed)	.000	.
		N	32	32
	Structural failure risk of ship owner	Correlation Coefficient	.673**	.615**
		Sig. (2-tailed)	.000	.000
		N	32	32

** . Correlation is significant at the 0.01 level (2-tailed).

For collision risk $r = 0.673$. P value = 0.000 Alpha value $\alpha = 0.05$. P value 0.000 is < Alpha value 0.05 so null hypothesis rejected and alternate hypothesis is rejected.

For grounding and foundering risk $r = 0.615$ P value = 0.000 Alpha value $\alpha = 0.05$. P value 0.000 is < Alpha value 0.05 so null hypothesis rejected and alternate hypothesis is accepted.

5 H0: (Null) There is no significant difference between charterer risk like operational seaworthy risk, lay time risk, delay and demurrage risk, payment and credit risk, cargo damage liability risk and legal risk.

H1: (Alternate) There is a significant difference between charterer risk like operational seaworthy risk, lay time risk, delay and demurrage risk, payment and credit risk, cargo damage liability risk and legal risk.

Table 5: SPSS Nonparametric correlation output

Nonparametric Correlations

Correlations

			Operational Seaworthiness Risk – Charterer	Laytime Risk – Charterer	Delay and Demurrage Risk – Charterer	Payment and Credit Risk – Charterer	Cargo Damage Liability Risk – Charterer	Legal Risk – Charterer
Spearman's rho	Operational Seaworthiness Risk – Charterer	Correlation Coefficient	1.000	.575**	.575**	.580**	.686**	.655**
		Sig.(2-tailed)	.	.001	.001	.000	.000	.000
		N	32	32	32	32	32	32
	Laytime Risk Charterer	Correlation Coefficient	.575**	1.000	.751**	.663**	.587**	.593**
		Sig.(2-tailed)	.001	.	.000	.000	.000	.000
		N	32	32	32	32	32	32
	Delay and Demurrage – Charterer	Correlation Coefficient	.575**	.751**	1.000	.724**	.566**	.614**
		Sig.(2-tailed)	.001	.000	.	.000	.001	.000
		N	32	32	32	32	32	32
	Payment and Credit Risk Charterer	Correlation Coefficient	.580**	.663**	.724**	1.000	.598**	.519**
		Sig.(2-tailed)	.000	.000	.000	.	.000	.002
		N	32	32	32	32	32	32
	Cargo Damage Liability Risk – Charterer	Correlation Coefficient	.686**	.587**	.566**	.598**	1.000	.858**
		Sig.(2-tailed)	.000	.000	.001	.000	.	.000
		N	32	32	32	32	32	32
	Legal Risk	Correlation Coefficient	.655**	.593**	.614**	.519**	.858**	1.000

Charterer	Sig.(2-tailed)	.000	.000	.000	.002	.000	.
	N	32	32	32	32	32	32

** . Correlation is significant at the 0.01 level (2-tailed).

In above output there is a positive correlation and mostly the p values are 0.000. So p value is < alpha value 0.05 so null hypothesis rejected and alternate hypothesis is accepted. So we can say that there is a significant relation between charterer risks.

6 H0: (Null) There is no significant difference between freight forwarder risks like total loss, loss of money, non-collection of documents, damage to the cargo.

H1: (Alternate) There is a significant difference between freight forwarder risks like total loss, loss of money, non-collection of documents, damage to the cargo.

Table 6: SPSS Nonparametric correlation output

Nonparametric Correlations

Correlations

		Total Loss Cargo Risk – Freight Forwarder	Loss of Money Risk – Freight Forwarder	Non- Collection of Documents Risk – Freight Forwarder	Damage to Cargo Risk – Freight Forwarder
Spearman's rho	Total Loss Cargo Risk – Freight Forwarder	1.000	.687**	.396*	.583**
	Correlation Coefficient	.	.000	.025	.000
	Sig. (2-tailed)	.	.	.	.
	N	32	32	32	32
	Loss of Money Risk – Freight Forwarder	.687**	1.000	.544**	.607**
	Correlation Coefficient	.000	.	.001	.000
	Sig. (2-tailed)	.000	.	.001	.000
	N	32	32	32	32
	Non-Collection of Documents Risk – Freight Forwarder	.396*	.544**	1.000	.666**
	Correlation Coefficient	.025	.001	.	.000
	Sig. (2-tailed)	.025	.001	.	.000
	N	32	32	32	32
	Damage to Cargo Risk – Freight Forwarder	.583**	.607**	.666**	1.000
	Correlation Coefficient	.000	.000	.000	.
	Sig. (2-tailed)	.000	.000	.000	.
	N	32	32	32	32

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

In above output there is a positive correlation and mostly the p values are 0.000. So p value is < alpha value 0.05 so null hypothesis rejected and alternate hypothesis is accepted. So we can say that there is a significant relation between freight forwarder risks.

7 H0: (Null) There is no significant difference between Importers/ Exporters risks like packing risk, loss of cargo, transportation delay, legal and compliance risk, warehouse management risk.

H1: (Alternate) There is a significant difference between Importers/ Exporters risks like packing risk, loss of cargo, transportation delay, legal and compliance risk, warehouse management risk.

Table 7: SPSS Nonparametric correlation output

Nonparametric Correlations

Correlations

	Damage due to Packaging Risk – Importer/Exporter	Lost Cargo Risk – Importer/Exporter	Transportation Delay Risk – Importer/Exporter	Legal Compliance Risk – Importer/Exporter	Warehouse Management Risk – Importer/Exporter
Spearman's rho					
Damage due to Packaging Risk – Correlation Coefficient	1.000	.659**	.652**	.626**	.558**
Sig. (2-tailed)	.	.000	.000	.000	.001
N	32	32	32	32	32
Lost Cargo Risk – Correlation Coefficient	.659**	1.000	.684**	.560**	.590**
Sig. (2-tailed)	.000	.	.000	.001	.000
N	32	32	32	32	32
Transportation Delay Risk – Correlation Coefficient	.652**	.684**	1.000	.624**	.420*
Sig. (2-tailed)	.000	.000	.	.000	.017
N	32	32	32	32	32
Legal Compliance Risk – Correlation Coefficient	.626**	.560**	.624**	1.000	.675**
Sig. (2-tailed)	.000	.001	.000	.	.000
N	32	32	32	32	32

Warehouse Management Risk – Importer/Exporter	Correlation Coefficient	.558**	.590**	.420*	.675**	1.000
	Sig. (2-tailed)	.001	.000	.017	.000	.
	N	32	32	32	32	32

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

In above output there is a positive correlation and mostly the p values are 0.000. So p value is < alpha value 0.05 so null hypothesis rejected and alternate hypothesis is accepted. So we can say that there is a significant relation between importer/ exporter risks.

8 H0: (Null) There is no significant difference between CHA risks like change in trade regulation risk, incorrect tariff risk.

H1: (Alternate) There is a significant difference between CHA risks like change in trade regulation risk, incorrect tariff risk.

Table 8: SPSS Nonparametric correlation output

Nonparametric Correlations

Correlations

		Changes in Trade Regulation Risk – CHA	Incorrect Tariff Documentation Risk – CHA
Spearman's rho	Changes in Trade Regulation Risk – CHA	1.000	.550**
	Correlation Coefficient		
	Sig. (2-tailed)	.	.001
	N	32	32
	Incorrect Tariff Documentation Risk – CHA	.550**	1.000
	Correlation Coefficient		
	Sig. (2-tailed)	.001	.
	N	32	32

** . Correlation is significant at the 0.01 level (2-tailed).

In above output there is a positive correlation and mostly the p values are 0.000. So p value is < alpha value 0.05 so null hypothesis rejected and alternate hypothesis is accepted. So we can say that there is a significant relation between CHA risks.

4. To study the development happened in marine cargo insurance in India and Europe.

Marine cargo insurance is the largest part of marine insurance domain in the world as below

Marine cargo insurance	56.9 %
Ocean hull	9.2 %
Offshore energy	4.6 %
Marine liability	3 %

Marine cargo insurance estimated value of \$22.1 B in 2023 and its expected CAGR growth of 3.4 % by 2032 reaching total market value \$29.9 B. Whenever international trade increases this segment also increases.

Top region ranks

Rank	Revenue 2023	Global Market
Europe	\$ 8.81 billion	39.8 %
Asia Pacific	\$ 7.13 billion	32.2 %
Others	\$ 6.2 billion	28 %

Source **Insurance 150**

Marine cargo insurance development in India and Europe

Development in India

Marine cargo insurance is derived from Marine insurance Act 1906 which is taken from British India. For the regulation in India in the insurance sector Insurance regulatory and development authority (IRDAI) came into force in 1999.

In March 2021, the parliament passed the bill to maximize the limit of foreign direct investment (FDI) from 49 % to 74 %

Source **Wikipedia**

2000 to 2005

After liberalization, privatization, globalization India opens the market for private sector and global insurers offer the insurance in India. TATA AIG formed in 2001. Headquartered in Mumbai, Maharashtra with the joint venture between TATA group and American International group (AIG) with equity shareholding of 74 % stake with TATA and 26 % with American international group. TATA AIG holds 6 % market share in the Indian general insurance market which is the third largest company in India. It offers general insurance products like automobiles, home, personal accident, travel, energy, marine, causality, property etc.

Source **Wikipedia**

2006 to 2010

In April 2005 firstly the Marine hull segment got detariffed.

On 1st January 2007 IRDAI removed the tariff. It is called detariffication from all general insurance. That means each and every company can charge their own prices. IRDAI did not intervene in pricing.

Source **SCRIBD**

2011 to 2015

The Indian government passed the insurance law which increased the FDI limit from 26 % to 49 %.

Source **IRDAI annual report 2015-16**

During this era the transition happened and Marine sales turnover policy was introduced. In this policy, policy holders have to declare the whole year sales import export goods. For all shipments, individual policy is not required.

Source **IRDAI**

2016 to 2020

In July 2017 the goods and service tax (GST) was introduced in India. Before GST the insurance premium service tax was 15 %. After GST implemented this rate went to 18 %.

Source **General Central insurance**

2021 to 2025

The co-founder of Qian insurance Mr. Umang Shah said that marine cargo insurance premium has increased 15 to 30 % depending upon the route, cargo, terms etc. Insurers are charging 0.10 to 0.15 % of the cargo value to cover war risk, hijacking, and piracy just because of the red sea crisis.

After the Russia - Ukraine war and red sea crisis the insurance premium for marine cargo insurance has increased. For example 50 crore shipments were shipped then the previous premium was 1.5 lakhs and now it is 6.5 lakhs with war risk premium. He said the exporters – importers of Gujarat and Maharashtra are significantly impacted.

In FY2025 Indian insurers reported the gross premium underwritten of RS 5535 crore for marine insurance out of this RS 3940 crore was marine cargo insurance.

Source **The Indian Express**

Uploaded Date and 17 June 2025

The U.S. is tariffing to India, so that insurer's income will increase because premium will increase.

But how will the premium increase?

If 100 crore worth of goods is exported from India and the tariff rate is 26 % so in the U.S. it will become 126 crore and the premium is calculated on the basis of invoice value. So that

the insurance premium will increase. So it is income for insurers and there is a loss for exporters and importers.

Source **The Economic Times**

Date 4 April 2025

During winter session Sabka Bima Sabki Raksha (Amendment of insurance laws) bill 2025 introduced. The bill stated 100 % FDI allowed in the insurance sector and regulators have to issue industry specific licenses which include marine insurance, cyber, property etc.

Irdai Can Issue Sector-Specific Licences

➤ Sector-specific licences will enable insurers to operate in single or niche lines of business such as cyber, property or marine insurance ➤ A key change is the shift from detailed statutory prescriptions to a regulation-driven framework, under which Irdai will set	 several operational norms through regulations rather than through Parliament-approved legislation ➤ The Bill also removes commission and remuneration caps for agents and intermediaries from the statute, giving the insurance regulator Irdai the authority to set these limits
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Source **The Times of India**

Upload on 16 December 2025

Development in Europe

2000 to 2005

In 1999 in the Bay of Biscay off the coast of France 10,000 tons of oil spilled from the Erika tanker due to a storm. It polluted 400 km of coastline. In 2002 oil tanker Prestige Sunk off the coast of Spain and France. In March 2000 the European council presented proposals referred to as Erika legislation which came into force on 22 July 2003. It is for oil tankers and dangerous goods transportation.

First proposal in the amendment: the vessel which was 15 years old and detained which ship was blacklisted by the commission and denied into the EU ports. They enforce stricter Port state inspection of ships.

The second proposal is a strict monitor of the classification society that checks the quality of ships on the behalf of the EU members. Whichever classification society is not following the directive commission has the right to suspend or withdraw the recognition.

Third proposal: replace the single hull tanker to the double hull tanker. From 1st January 2010 in the internal water of Europe complete ban of 20,000 DWT of crude carrier and 30,000 DWT of product tanker with single hull carrier.

The aim of these amendments is to minimize the cargo loss.

Source [Wikipedia](#)

2006 to 2010

The European Union Directive 2009/20/EC proposed in 2009 and it came into force on 1st January 2012. The Directive requirement is compulsory each and every vessel has to take P & I cover either it is a European Union flag vessel or other flag vessel. If any vessel does not comply with this Directive the vessel entry is not permitted to any port of Europe.

Source [Wikipedia](#)

2011 to 2015

The insurance act 2015 is a UK act of parliament which reforms the insurance law. It came into force on 12 August 2016. European insurers and brokers implement this new act in the UK and beyond the UK in marine cargo insurance.

According to this new act insurers have to pay claim payment on agreed time periods.

Source [Wikipedia](#)

The final draft of Rotterdam rule was assembled by the united nation commission on international trade law. It was adopted by the United Nations on 11 December 2008. The signing ceremony was held in Rotterdam on 23 September 2009. On the same day the United States, France, Greece, Denmark, Switzerland and Netherland signed and agreed to ratify the Rotterdam rule. On 9 August 2011 24 countries ratified this rule including Spain.

Source [Wikipedia](#)

2016 to 2020

Solvency II framework introduced in EU. Which was applicable from 1st January 2016 in EU. It affects life insurance, non-life insurance and reinsurance. This framework includes Directive, delegation acts and technical standards.

Pillar 1 Risk based capital requirements

In order to ensure that they have the financial resources to weather financial challenges, the regulation mandates that the insurance companies keep capital in proportion to their risk profiles.

Pillar 2 Governance and risk management requirements

Insurance companies have to

Provide a sufficient and open governance framework.

Regularly evaluate their own risk and solvency.

Pillar 3 Supervisory reporting and public disclosure

The directive

Allows supervisors to examine and assess whether insurance businesses adhere to the regulations.

Mandates that these businesses provide reports to oversight bodies and make information available to the public.

Source **European Commission**

2021 to 2025

Cargo insurance returned a global premium base for 2023 of USD 22.1 billion with 6.2% improvement on 2022. All regions witnessed growth with Europe and Asia have strong positive development. Overall, Europe claimed a 39.8% share followed by Asia/Pacific (32.2%), Latin America (11.9%), North America (7.5%), Middle East (6.0%) and Africa (2.7%). In general, premium growth in this industry follows global commerce which has now normalized after COVID.

Source **IUMI**

Learning for India from EU market

Solvency II like framework can be applicable in India so insurers have sufficient amount of money for compensation and cargo claim rejection can be minimized.

As per insurance act 2015 insurers have to pay claim amount in the agreed time.

Europe heavily relies on IUMI (International union of marine insurance) data IRDAI also publishes India specific data of loss of cargo, route wise cargo loss etc.

Europe strongly works on compliance and strengthening the vessel operations norms to reduce the cargo loss. Same thing India can draft their own rules and regulations.

Conclusion

Global trade is dependent on marine transportation. If marine transportation suffers from any limitation then the supply chain can be disrupted. In this unstable geopolitical uncertainty, war like situation the marine cargo insurance becomes compulsory for the shipper.

Solvency II like framework can be applicable in India so insurers will have sufficient amount of money for compensation and cargo claim rejection can be minimized. As per Insurance Law Amendment Act 2015, insurers have to pay claim amount in the agreed time. Europe heavily relies on IUMI (International union of marine insurance) data. IRDAI also publishes India specific data of loss of cargo, route wise cargo loss etc. Europe strongly works on compliance and strengthening the vessel operations norms to reduce the cargo loss. India can draft their own rules and regulations. Vessel condition disclosure can increase the chance of claim acceptance.

This study highlights the importance of marine cargo insurance in marine transportation. This study is divided into four objectives.

First objective dwells deep into major accidents and cargo losses on the 10 major trade routes and deadliest container maritime route through case studies. This study helps shippers to know reasons for the cargo claim rejection. This study provides a practical case study and practical reasons for the marine cargo claim rejection. The second objective highlights practical reasons for cargo claim rejections. The third objective clarifies practical challenges of various stakeholders and correlation between technical issues in the vessel

and impacts on cargo insurance, cargo hold condition and impacts on marine cargo insurance and transparency of vessel and impacts on cargo insurance. And the fourth objective highlights the development in India and Europe about solvency clauses and its contribution to both insurer and insured.

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Financing Port Infrastructure Development in Gujarat

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Abstract

With particular reference to financial performance and Public-Private Partnerships (PPP), this study intends to investigate and analyse the financing of port infrastructure development in Gujarat. Ports are crucial to trade and economic growth. However, significant capital investment is needed for their development and operation, making an effective financing plan crucial. This research methodology is based on descriptive and analytical approach that makes use of secondary research techniques. The research has used annual reports and other financial statements of Deendayal Port and Pipavav Port for conducting a comparative study of these ports. The research has found that Deendayal Port has been following a consistent and stable approach of investing revenue generated through business activities, resulting in continuous development of infrastructure, whereas Pipavav Port has been investing in phases and investing more during expansion periods and less during other periods. The research has also proved that PPP plays an important role in financing port infrastructure development and alleviates the financial burden of the government. The research has concluded that for the development of port infrastructure in Gujarat, it is essential to maintain a balance between financial stability and PPP.

Keywords: Port Infrastructure, Public–Private Partnership (PPP), Financial Performance, BOT, BOOT, DBFOT

Introduction

The maritime transport industry is a critical part of the operation of the global economy since it helps to transport goods between nations and continents. More than 80 percent of global trade is estimated to occur via the sea routes and ports are considered to be one of the most important elements in international trade and international logistics systems. Ports have evolved over the years since they are no longer a mere destination where cargo is loaded and unloaded but a complex logistics centre, which incorporates transportation, warehousing, and supply chain management activities. This change has made ports crucial in facilitating economic growth, industrial growth as well as competitiveness in international trade. Due to the growth of the global trade and the constant growth of the vessels size and cargo volumes, the requirements in the effective and modern port infrastructure became active and increased manifold. The ports today are supposed to accommodate huge container ships, bulk cargo vessels, and special vessels, which have led to the need to develop deep draft berths, sophisticated cargo handling systems, and effective hinterland connectivity. Moreover, the contemporary ports are more and more being automated, digitalized, and offered with green and sustainable solutions like green energy infrastructure to enhance the efficiency of port operations and to decrease environmental impact. Such developments show that the port infrastructure is no longer based on physical development but also technological development and sustainability. The construction and modernization of the port infrastructure, however, is expensive. Port projects are generally capital intensive in nature and they have long gestation periods, high risk of operation and unpredictable returns.

There is need to invest not only in building new ports and terminals (greenfield projects) but also renovating the current ones (brownfield projects) to support the evolving trade requirements. Other infrastructure issues like railway access, road networks, container hubs, storage systems, and security mechanisms make the financial burden even higher. Consequently, funding port infrastructure development has emerged as one of the key challenges of port authorities and policymakers in the whole world. Conventionally, the development of port infrastructure has been funded by the public sector, by which they mean the government budget, grants and by the institutions. Although the strategy served well during the initial years of growth, it has of late been extremely challenging to maintain as the infrastructure expenditures, budget limitations and other conflicting needs on the same resources grow. The increasing financial demands of port development can no longer be met only by governments and most importantly in developing economies where the infrastructure demand is great. This has necessitated the need to have other sources of financing that are able to marshal more funds and have efficient project implementation. In reaction to such challenges, a move to diversified financing plans with the involvement of the private sector has taken place all over the world. Among the significant advancements in this regard is the use of Public Private Partnerships (PPP) models in the development of the port infrastructure. PPP is a joint arrangement between government and the privates whereby both parties have combined roles, risk and rewards of infrastructure projects. The models allow governments to harness the resources of the privates, technical skills, and management efficiency without having to strain their budgets. PPP models have different types that are applied in the financing of the port infrastructure based on the nature and size of the project. The typical models are Build-Operate-Transfer (BOT), Build-Own- Operate-Transfer (BOOT) and Design-Build-Finance-Operate-Transfer (DBFOT). The two models are dissimilar with regards to ownership, sharing risk and the period of concession. To cite an example, DBFOT is usually employed on large and high-risk projects in which the financing, building, and long-term operation is conducted by private investors in the projects. Conversely, BOT models are applied in order to make certain infrastructure enhancements in the existing ports. Such models are not as rigid in project design and enable efficient distribution of risks between the public and the private stakeholders. The current growth in the use of PPP models has led to rapid growth in the port infrastructure through the attraction of private investment and efficiency in the operation. Innovation that comes with the participation of the private sector, improved technology and improved management practices are beneficial to the overall performance of ports. Concurrently, PPP models contribute towards speeding up the implementation of projects and eliminating delays that are mostly characteristic of projects that are funded by the government. The success of PPP projects however is determined by a number of factors such as transparent regulatory frameworks, risk management, clear contractual obligations, and good institutional support. The policy uncertainty, legal problems, and delays in approvals are only some of the challenges that may influence the performance of PPP projects and restrain their performance. The financial performance of ports is also vital in the development of infrastructure as well as financing mechanisms. Financial performance is based on the ability of a port to make profit, control expenses and invest in development. Ports that have a high financial performance are in a better position of undergoing unending infrastructural development and modernization whereas those that have a poor financial structure may be restricted in their capacity building. Thus, it becomes necessary to analyse the trends in financing and investment behaviour in order to comprehend the way ports use their resources and set up the development strategy. It is within this context that the current research seeks to examine how port development is financed and the contribution of Public-Private Partnership (PPP) as far as the growth of infrastructure is concerned. The research aims at comprehending the role played by various financing mechanisms in the development of infrastructure and the use of PPP models in mobilization of resources, sharing of risks, and efficiency. Through the study

of these points, the research will attempt to offer the understanding of the best methods of funding the development of sustainable port infrastructure.

Literature Review

Basic Concepts of Port Infrastructure Financing

Infrastructure financing of port infrastructure is a capital-intensive project and traditional financing through the state is no longer adequate to fund the increasing infrastructure. The paper has indicated the significance of diversified sources of funds like, source of private capital, loans and the financial markets to make ports sustainable and competitive in the long run. (Meersman et al., 2014). But as these projects have far reaching impact and are of importance for the economy, the government should also fund. Despite overall benefits of port projects total, the proportion of public investment is low, which implies that alternative financing instruments should be used in this case. (Dekker et al., 2003). Has an additional cost impact on the government and some problems in the traditional systems of public financing in that the burden of financial risks is on the governments in the development of the ports. It is implied that project-based financing is more effective because it shifts risks onto the side of private players and enhances decisions in terms of investments. (Blumenthal, 2005). The need for more efficient financing models such as PPP issue of the monetary cost of port reforms and the increase in the importance of the PPP in infrastructure development. It also talks of the significance of risk-sharing, financial modelling and long-term funding strategies in port projects. (World Bank, 2007)

Financial Structures & Investment Models

The paper describes the model of the landlord port, in which the investment duties are distributed between parties including the port and authorities as well as private operators. It also brings out financial risks and the necessity of collective financing to provide efficient development of infrastructure. (Somorowsky et al., 2020). The growing role of private investors in port financing or concept of financialization of ports where the significant contribution is made by the financial partners who are usually the private investors, banks, and international operators in funding the infrastructure. It draws light to valuation methods, fund raising issues and effects of financial framework on port competitiveness. (Notteboom et al., 2022). The importance of good financial planning is for port investments. The economic contribution and profitability of port investments, with the focus being on the need to have the correct financial planning and cost-benefit analysis as far as the development of sustainable infrastructure is concerned. It also connects investment decisions and trade growth and efficiency. (Musso et al., 2006)

Financial Performance & Investment Behaviour

The paper examines how security policies affect the financial performance of a port and brings out the fact that rising operation and maintenance expenses negatively influence financial sustainability. It demonstrates the significance of financial planning in the development of infrastructure. (Kruse et al., 2005) strong financial performance for infrastructure investment based on financial analysis of ports in terms of such indicators as profitability, liquidity and solvency. It concludes that financially powerful ports have a greater potential to make investments in the development of infrastructure. (Vasumathi et al., 2024).

Economic Impact of Port Development

The paper elaborates on how investment in port infrastructure contributes to trade and economic wellbeing by a huge margin. It also emphasizes spillover effects where one port development is advantaged to other regions. (Brancaccio et al., 2024). There are also such economic gains as regional development and job creation. The ports in regional growth, creation of job opportunities and industrial development particularly in the Saurashtra and

Kutch regions of Gujarat. (Tiwari, 2011). This effect is regional and is also shown in the general economic development of the state. Port development has a close correlation to the Gujarat economic growth (GSDP). It draws the focus to the fact that better connectivity and infrastructure improve exports and long-term growth. (Kharva et al., 2024).

Innovation, Risk & Future Development

The paper describes how port innovation is primarily funded by the players, and development guided by the port authorities. It points out the relevance of coordination in technological development. (Blanco et al., 2011). The same coordination with respect to the financing strategies among the various stakeholders. The mode of port financing and the need to have co-opetition amongst the interested groups to realize the attainment of competitive advantage and effective infrastructure development. (Fraser et al., 2021). Long-term project success also involves appropriate risk management in order to have good financing strategies. significance to risk management in major port projects, and it is noted that risk analysis and correct planning are critical as the cost and payback period is lengthy and expensive. (Ho et al., 2006). Structural reforms in port development have also been as a result of such considerations of risks. Reforms in the port of India and brings to light the benefits of privatisation development, efficiency and infrastructure modernisation in the development of ports. (Ray, 2004). Such developments have also promoted the use of modern technologies in the running of ports. smart port with the help of ICT, automation, and digital technologies to enhance the efficiency, sustainability, and competitiveness. (Yau et al., 2020). Nevertheless, legal and regulatory framework is also required in the implementation of such advancements. legal and regulatory issues associated with port projects, which indicates that ambiguous policies and conflicts may slow down the development of infrastructure and raise its costs. (Raghuram et al., 2017)).

Public–Private Partnership (PPP) as Core Financing Model

The research identifies PPP as one of the models that are important in the Indian port infrastructure to enhance efficiencies and boost the investment by the companies in terms of BOT, BOOT, and DBFOT models. Its performance is however hampered by regulatory issues and delays. (Barik, 2024) all these obstacles also demonstrate the existence of financial risks in PPP projects. Major financial risk in PPP port projects as identified by this research includes high cost of capital and uncertainty in revenue. It stresses on the necessity of adequate risk assessment solutions such as NPV and simulation methods. (Raut & Vyas, 2023). These risks should be managed so that the benefits of PPP models can be completely achieved. PPP helps decrease the financial load of the government through the use of the private capital, technology and expertise. It emphasizes that effective projects require effective risk-sharing and agreements. (Geoffrey et al., 2014). Financial institutions also contribute towards such PPP frameworks by assisting in the management of funding and risks. Or how Development Finance Institutions (DFIs) contribute to the provision of PPP projects in terms of financing the projects over a long term and mitigating risks. It also points out such challenges as the issue of governance and coordination. (Eke & Dike, 2025). Nonetheless, the wider scope implementation issues continue to impact on the success of PPP projects. but issues of the projects of the PPP implementation in India, including the instability of the policies, the delays in approvals, the aggressive bidders. It concludes that it is necessitated by better planning and policy support to succeed. (Raghuram & Shukla, 2014) These challenges should also be addressed to attain sustainable port development using the PPP. The project is one concerned with PPP when it comes to sustainable development of ports and gives significance to governance, stakeholder involvement and long-term policy consistency. It also addresses such risks as bad project choices and cost explosion. (Schroeder, 2019). additional risks that underscore the importance of adequate evaluation and planning of projects. PPP projects and points out such problems as miscalculated demand, and cash closure lag. It highlights the importance of the adequate

feasibility studies and evaluation systems. (Kurniawan, 2013). Need to have the increased involvement of the private sector in infrastructure development is also exhibited in these implementation challenges. Involvement of the private sector in the development of infrastructure because of the financial limitations of the government. It points to such challenges as the legal problem, time-delays, and insufficient transparency. (Rout, 2017). The institutional and regulatory frameworks need to be strong in order to address these challenges discusses institutional issues and regulatory frameworks Issues that influence the success of PPP and concludes conclude that effective regulation systems and governance enhance the success of the private investments and projects. (Panayides et al., 2015)

Objectives

1. To analyse the financing of port infrastructure development in Gujarat.
2. To study the role of Public–Private Partnership (PPP) in port infrastructure development in Gujarat.
3. To provide recommendations for port infrastructure financing and development based on financial analysis.

Research Methodology

1. **Research Design:** - The present study adopts a descriptive and analytical research design. The descriptive approach is used to examine the investment patterns in port infrastructure development, while the analytical approach is used to evaluate the financial performance and the role of Public–Private Partnership (PPP) in port infrastructure financing. The study analyses financial data and PPP project information related to selected ports in Gujarat.
2. **Source of data:** - The study is based on secondary data collected from reliable sources. The data has been obtained from:

Objective-1: - data source Annual reports of **Deendayal Port Authority** Financial results and investor reports of **APM Terminals Pipavav**

Objective-2: - Government PPP databases and reports, Shipping industry publications and official port websites, Research articles and infrastructure development reports, these sources provide information regarding infrastructure investment, revenue performance, and PPP projects in port development.

Discussion

(1) To analyse the financing of port infrastructure development in Gujarat.

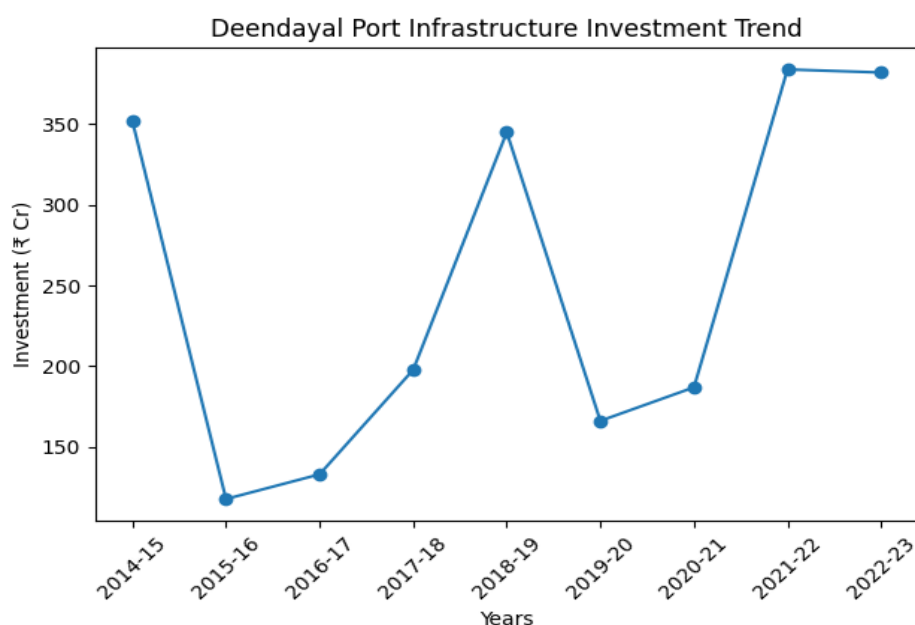
Study of development of port infrastructure in Gujarat. I selected two ports In Gujarat first is Deendayal port and second is Pipavav port. So, I have study in both port infrastructure how much reinvests in every year wise and how to manage a fund investment in infrastructure.

Table 1: Investments in Deendayal Port from 2014-15 to 2022-23

Year	Particulars	Amounts Rs in Cr.
2014-15	-	351.80
2015-16	-	117.68
2016-17	-	132.98

2017-18	Construction of berth, rail or road connectivity, smart port city	197.78
2018-19	Construction of berth, rail or road connectivity, smart port city	345.07
2019-20	Construction of berth, rail or road connectivity, smart port city	166.13
2020-21	Construction of berth, rail or road connectivity, smart port city	186.92
2021-22	Construction of berth, rail or road connectivity, smart port city	384.01
2022-23	Construction of berth, rail or road connectivity, smart port city	382.1

Descriptive: - In 2021-22, the Deendayal Port Authority made the biggest investment in infrastructure at 384.01 crore, which means that it focuses on modernization and capacity development. The minimum capital expenditure was recorded in 2015-16 and is 117.68 crore, which indicates a short-term slowdown in capital expenditure.



Explanation: - Based on the graph of Deendayal Port Authority, it is perceived that the trend of investment is quite constant though subject to fluctuations. The port keeps on making investments annually though the sum varies. It has some low investment years (as in 2015-16), but the general tendency is that there has been consistent reinvestment. This is a

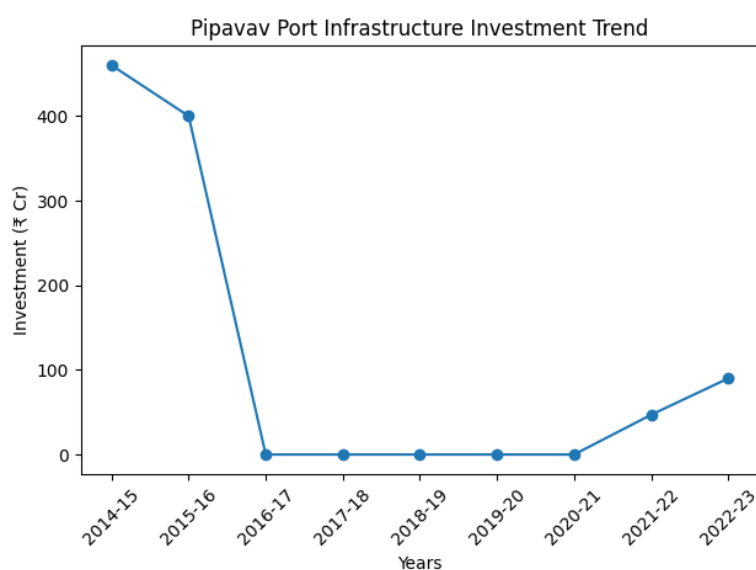
pointer that the port has a linear and sustained development process, which does not emphasize on a rapid expansion of infrastructure, but focuses on the long-term development of infrastructure.

Source: - <https://www.deendayalport.gov.in/en/downloads/reports/>

Table 2: Investment in Pipavav port from 2014-15 to 2022-23

Years	Particulars	Amounts Rs in Cr.
2014-15	Development of container yard, berth, internal road or some extra infrastructure for business requirement.	460.00
2015-16	Completion of capacity expansion (new STS cranes, berth strengthening, dredging, yard/road works)	400.00
2016-17	-	-
2017-18	-	-
2018-19	-	-
2019-20	-	-
2020-21	-	-
2021-22	Development of Railway Infrastructure, Construction of Warehouse, Upgradation of existing liquid jetty to handle VLGC Vessels,	47.00
2022-23	Upgradation of existing liquid jetty, Development of Railway Infrastructure for DFC Corridor Compatibility, Upgradation of Fire Fighting System at Liquid Jetty, Rail Replacement at RMGC Yard, Construction of pedestrian walkway at Fertilizer Shed	90.00

Descriptive: - It is observed that APM Terminals Pipavav experienced a significant period of expansion in terms of investments in 2014-15 with a peak investment of 460 crore. The least investment is recorded between the years 2016-17 to 2020-21 where no major investment was done which means there was a gap in infrastructure development.



Explanation: - The pattern of investment as of APM Terminals Pipavav is irregular as might be seen based on the graph of the terminal. It is observed that the port invested heavily during the initial years (2014-16), and then did not invest in upcoming years, and later started making smaller investments. This demonstrates that the port has a phased or selective investment approach such that it invests a lot when the expansion periods arise and then concentrates on operations of other years.

Source: - <https://www.apmterminals.com/en/pipavav/investors/financial-results>

Comparison of Current Year Infrastructure Investment with Previous Year Revenue: A Study of Deendayal and Pipavav Ports

Table 3: Comparison of past revenue to current year infrastructure.

Year	Infrastructure Investment (₹ Cr)	Previous Year Revenue (₹ Cr)	% of past years Revenue Invested in infrastructure
2014-15	351.80	1,008.04 (2013-14)	34.9%
2015-16	117.68	1,048.27 (2014-15)	11.2%
2016-17	132.98	1,189.40 (2015-16)	11.2%
2017-18	197.78	1,571.85 (2016-17)	12.6%
2018-19	345.07	1,736.46 (2017-18)	19.9%
2019-20	166.13	1,846.90 (2018-19)	9.0%
2020-21	186.92	1,966.50 (2019-20)	9.50%
2021-22	384.01	1,789.10 (2020-21)	21.46%
2022-23	382.10	2,004.80(2021-22)	19.05%

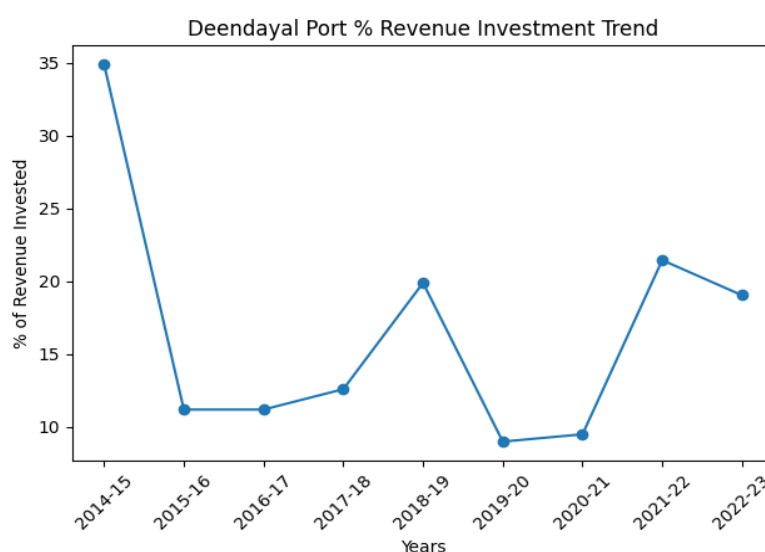
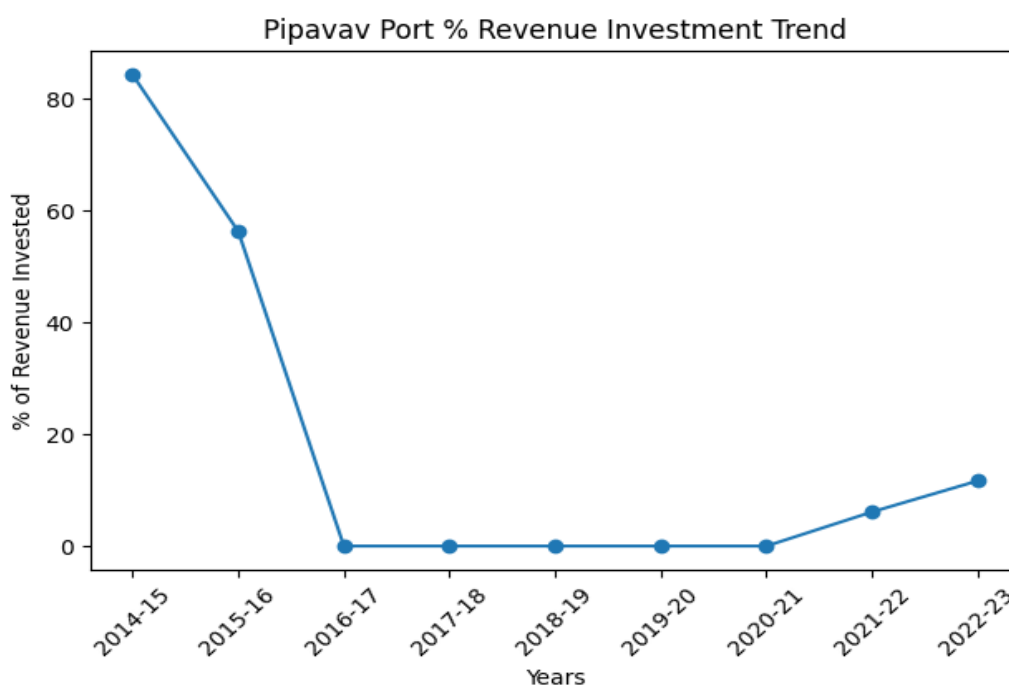


Table – 4

This table data is discussed and compare about Pipavav port

Year	Infrastructure Investment (₹ Cr)	Previous Year Revenue (₹ Cr)	% of Revenue Invested
2014-15	460.00	546.00s (2013-14)	84.25%
2015-16	400.00	711.00 (2014-15)	56.26%
2016-17	–	698.00 (2015-16)	–
2017-18	–	718.00(2016-17)	–
2018-19	–	684.00 (2017-18)	–
2019-20	–	738.00(2018-19)	–
2020-21	–	782.00 (2019-20)	–
2021-22	47.00	773.86 (2020-21)	6.1%
2022-23	90.00	772.13 (2021-22)	11.65%



Source: -

The pattern of investment as of APM Terminals Pipavav is irregular as might be seen based on the graph of the terminal. It is observed that the port invested heavily during the initial years (2014-16), and then did not invest in upcoming years, and later started making smaller

investments. This demonstrates that the port has a phased or selective investment approach such that it invests a lot when the expansion periods arise and then concentrates on operations of other years.

Interpretation of 1st objective

- The data presented in Deendayal Port shows that it conducts consistent planning of its finances regularly and balances revenue and infrastructure investments. Contrarily, Pipavav Port depicts changes in the level of investments thus indicating a gradual or uncertain way of investing. Such a gap demonstrates differences in long-term financial discipline and development of infrastructure planning.
- The discussion of capital expenditure on the development of port infrastructure at Deendayal Port (previously Kandla Port) between 2014-15 and 2022-23 shows that there is a volatile but mostly consistent trend. In the year 2014-15, the amount spent on infrastructure development was 351.80 crore that was approximately 34.9% of the revenue in the preceding year. This was a big move toward the enhancement of infrastructure then. However, in 2015-16 and 2016-17, the investment on decrease to 117.68 crore and 132.98 crore, respectively, about 11.2 per cent of revenue. This indicates that capital growth became sluggish in the short-run.
- Since 2017-18 The port has made the second increase of its investments to support the construction of new infrastructure, including smart port development, constructions, rail and road links and others. In 2018-19, it increased investment to 345.07 crore or 19.9 percent of revenue. This demonstrates that the emphasis is made on enhancement of the port capacity and logistics infrastructure again. Due to the issue with operations and economy, the investment dropped to 166.13 crore in 2019-20. Nevertheless, in 2021-22 and 2022-23, the port increased its capital expenditure, to 38401 crore and 38210crore, respectively. These investments constituted 21.46% and 19.05% of revised showing a solid financial investment in modernisation and the growing capacity.
- Another trend in investment is however reflected in Pipavav Port. APM Terminals Pipavav operated it. In the first few years, the port has frittered away cash by building the infrastructure. It incurred 460 crores in 2014-15 constituting 84.25 percent of its revenue last year. It also incurred expenditure of 400 crores in 2015-16, which is 56.26 percent of its revenue last year. This will entail significant capacity building and modernisation of the port through building of new container yards, strengthening the berths, dredging and installing latest ship-to-shore cranes
- After 2016-17 to 2020-21, however, the port did not make significant infrastructure investments or very few of them. This implies that previous capital ventures had already established sufficient capacity and the port was more geared towards increasing its operations. Investment activity returned in 2021-22 and 2022-23 with 47 crore and 90 crores respectively being invested in the construction of new warehouses, as well as the upgrading of jetties and ensuring that the Dedicated Freight Corridor (DFC) network functions with the new infrastructure. such as the modernisation of network and the enhancement of its fire-fighting system. The investments are limited to contributing from 6-11% of the yearly revenue, yet they demonstrate an organizational strategy of small upgrades in the infrastructure rather than massive expansions.
- Both portfolios have varied approaches to investment according to the financial performance analysis. Whereas Pipavav Port a privately owned port normally invests heavily during periods of expansion and then switches to minor upgrades in its operation, Deendayal Port Authority, which is a government port, is a periodical investor in large infrastructure upgrades to facilitate the development of national trade. The given comparison proves that the financial capability, ownership structure, and strategic goals

shape the decision-making process concerning the infrastructure investment in the port industry.

- There are various structural indicators that are disclosed in relation to the two ports. Deendayal Port which is one of the larger government-operated ports continues to keep the national trade and also allows the infrastructure to keep on developing continuously as it is able to approach investment in a more consistent and predictable manner. Although Pipavav Port is a privately-owned port, it applies a cyclical approach to investment whereby its operation is optimized at the periods when its expenditure is low and capital investment is made at the periods when its expenditure is high.
- Hence, the trend analysis indicates that in case of the public ports, stability of the infrastructure on a long-term basis is the concern, but in case of the private ports, strategic growth and profit based investment cycles are pursued. These variations indicate the varying interests of the development of the public sector infrastructure and commercial operations in the port sector by the private sector.

(2) To study the role of Public–Private Partnership (PPP) in port infrastructure development in Gujarat.

Years	Projects	Port	PPP model	Developer	Investment in Cr.
2019	CNG Terminal expansion	Bhavnagar Port	BOOT	Foresight Group	4,000.00
2021	Container-Capacity Expansion	Pipavav Port	BOOT/Privet concession	APM Terminal Group	700.00
2023	Container Terminal at Tuna-Tekra (Cabinet approval)	DPA	BOT	DP World	4,539.00
2024	Oil Jetty No. 09	DPA	BOT	DPA has not qualified a company name	123.00
2024	Berth 13	DPA	DBFOT	Adani Port	169.00
2025	Port expansion	Pipavav Port	PPP – Private Concession Agreement	APM Terminal Group	17,000.00

Source: -

<https://www.dholerametrocity.com/News-Behind-the-world-s-first-CNG-terminal-at-Bhavnagar-Gujarat.php>

<https://economictimes.indiatimes.com/industry/transportation/shipping-/transport/apm-terminals-pipavavs-board-approves-rs-700-cr-expansion-plan/articleshow/77705546.cms>

https://shipmin.gov.in/sites/default/files/Update%20on%20Indian%20Ports%20Sector%20upto%2031.03.2025_0.pdf

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<https://cmogujarat.gov.in/en/latest-news/pipavav-port-mou-gujarat-maritime-board?>

Interpretation of 2nd objective

- The case study of the PPP projects in Gujarat ports (2019-2025) indicates that the Public-Private Partnerships have turned out to be a significant source of the financing of the large-scale infrastructure development of the port. The information shows that various PPP models have been adopted like BOT, BOOT, DBFOT and private concession agreements depending on the type and size of the project.
- As can be seen in the table displaying the projects, the high-value investments are mostly linked with PPP models. An example is the CNG Terminal expansion of the Bhavnagar Port (₹4,000 crore), Tuna-Tekra Container Terminal of the Deendayal Port (₹4,539 crore), and the proposed expansion of the Pipavav Port (₹17,000 crore) all of which is clear evidence that large infrastructure projects are largely reliant on the participation of the private sector.
- It is also noted that PPP models are adopted by different ports depending on their strategic needs. BOT and DBFOT models have been applied by Deendayal Port Authority in the expansion of infrastructure like container terminals, oil jetties and berths. Conversely, Pipavav Port is a private port and therefore has the added advantage of depending more on the private concession and direct investment into expansions.
- The other significant point to note is that PPP projects are largely concentrated in capital-intensive infrastructure projects like container terminals, jetties and port expansion projects. This shows that PPP is more applicable in projects that demand high financial investment and development over a long period of time.
- In addition, the 2019-2025 trend indicates that the nature of investments is increasing, meaning that the dependence on PPP is increasing. The involvement of more and more players, such as the APM Terminals, DP World, and Adani Ports, indicates the significance of the role of the capital, technologies, and efficiency of operations in the development of ports as part of the privatization.
- On balance, the data show that PPP is rather essential to decrease the number of finances used by the government and provide quicker and more effective infrastructure development. But then, PPP projects can be effective under the condition of their appropriate structuring, agreement, and long-term planning.

(3) To provide recommendations for port infrastructure financing and development based on financial analysis.

Using the financial performance of the chosen ports (Objective 1) and the impact of Public-Private Partnerships (PPP) on the infrastructure development (Objective 2), the next recommendations can be expressed to enhance the efficiency, sustainability, and financing of the port infrastructure in Gujarat.

1. Using a Balanced Investment Approach

According to the analysis, Pipavav Port uses a phased investment strategy with lengthy gaps, while Deendayal Port has a consistent investment pattern.

Recommendation

Ports should implement a balanced investment strategy that maintains a minimum level of annual investment while increasing it during times of expansion.

Justification

This will guarantee ongoing infrastructure development and facilitate major expansion when needed.

2. Creating a Connection Between Investment and Revenue

According to the data, Pipavav Port does not consistently maintain a relationship between revenue and investment, whereas Deendayal Port invests a specific percentage of its revenue.

Recommendation

In order to ensure that revenue growth is accompanied by commensurate infrastructure development, ports should maintain a set percentage of revenue for infrastructure investment.

Justification

This helps maintain financial discipline and ensures sustainable growth.

3. Avoidance of Protracted Investment Gap

The study has revealed that Pipavav Port had an elongated period (2016-2021) during which there were no capital investment initial

Recommendation

The authorities should avoid long gaps in investment initiatives and ensure the development of the port through periodic investment.

Justification

This will help avoid obsolescence in infrastructure and reduce the need to make large-scale capital investment.

4. Strategic Deployment of Public-Private Partnerships (PPP) for Large-Scale Projects

The PPP analysis revealed that projects involving large capital outlays (₹4,000 Crores and above) were undertaken through PPP.

Recommendation

PPP should be adopted for large-scale projects involving capital investment, like container terminals, development of the port, etc.

Justification

This will help mobilize capital and reduce the burden on the government.

5. Balanced Dependence on Public-Private Partnerships (PPP) and Internal Financing

From the findings, it is evident that PPP is a significant factor in large-scale investment initiatives, while internal financing is a backbone in routine development activities.

Recommendation

Ports should maintain a balanced source of funds by relying on: - Internal financing in routine infrastructure development activities, PPP in large-scale expansion projects.

Justification

This will enhance efficiency in investment and infrastructure development.

6. Enhancement of Project Planning and Investment Phasing

The analysis of the available PPP project data revealed that there were variations in project scale and project timing, and there were no indications of project phasing.

Recommendation

The ports should consider adopting a long-term project planning approach that phases small, medium, and large projects.

Justification

This strategy is expected to improve the efficiency of fund utilization and infrastructure development.

7. Integrated Development Approach

The overall assessment revealed variations in investment behaviour and an increasing trend towards the adoption of PPP models.

Recommendation

The ports should consider adopting an integrated approach to project development, which integrates the following strategies:

A consistent investment strategy, as adopted in Deendayal Port.

A flexible investment strategy, as adopted in Pipavav Port.

An efficient application of PPP models in large projects.

Justification

The integrated approach is expected to ensure sustainable, efficient, and balanced infrastructure development in the ports of Gujarat.

Conclusion

It is pertinent to mention that the significance of the current study lies in the comprehensive examination of the financing mechanisms underlying the development of port infrastructures. This study examines the ways in which the financial resources are mobilized and utilized in the development of port infrastructures through internal revenue generation, investment, and Public-Private Partnership models.

This study compares the financial models for a public port, i.e., Deendayal Port, and for a private port, i.e., Pipavav Port, which clarifies the differences in the investment strategies adopted in the development of infrastructures for both public and private sector.

Significance of the current study lies in the fact that the findings are useful in the financial planning and decision-making processes pertinent to the development of port infrastructures, which are imperative for the stakeholders involved in the process. The current study is important in the sense that it adds value to the existing literature in the form of empirical evidence regarding the role of Public-Private Partnerships in the development of port infrastructures in Gujarat.

Financial performance and the increasing trend of Public–Private Partnerships (PPP) are the major factors influencing port infrastructure finance in Gujarat. The study of the infrastructure finance of Deendayal Port and Pipavav Port helps in concluding that the investment patterns of the ports are not the same. The infrastructure finance of Deendayal Port is based on a stable and consistent pattern of investments. The port reinvests a fixed

percentage of its income in the business. This has helped the port in sustaining its infrastructure development. On the other hand, the infrastructure finance of Pipavav Port is based on a phased and selective pattern of investments. The port spends heavily during the expansion period and minimally during other periods.

Another important conclusion drawn by the study is that the Public–Private Partnerships (PPP) have become an important factor in infrastructure finance. Large-scale infrastructure development in Gujarat is based on the BOT, BOOT, and DBFOT modes of PPP. These modes help the government in mobilizing private sector finance and reduce the financial burden on the government.

Financial performance of ports leading to availability of internal finance and effective involvement of the private sector in the form of Public–Private Partnerships are playing key roles in the development of port infrastructure. Ports are important for providing a base for internal trade as well as international trade hence their efficiency and growth are vital for any economy. An integrated approach is required for the development of port infrastructure.

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Impact of Global Disruptions on Freight Rates in Container Shipping

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Abstract

This research studies the Impact of Global Disruption on Freight Rates in Container Shipping, focusing primarily on the COVID-19 pandemic. Container shipping carries 80–90% of global goods, making freight rate stability critical to international trade. The study uses a mixed research design, combining primary data from freight forwarding companies with secondary data from indices such as SCFI and Drewry's WCI. Three objectives were examined: the impact of COVID-19 on freight rates, the role of surcharges in inflating costs, and the effect of rate volatility on freight forwarders. Analysis revealed that freight rates surged from 2019 to 2021, while container availability fell. The study concludes that global disruptions create unequal cost burdens, shipping lines earned record profits while forwarders and consumers suffered and recommends surcharge regulation, container buffer reserves, smarter forecasting, and stronger contractual protections to build a more resilient shipping ecosystem.

Keywords: Freight Rates, Covid-19 Pandemic, Container Shipping, Surcharges, SCFI, WCI Global Disruptions, Volatility.

Introduction

International trade depends heavily on container shipping, as it carries around 80–90% of global goods. Freight rates in container shipping play a vital role in determining the cost of trade, competitiveness of industries, and consumer prices across the world. Normally, these freight rates are influenced by supply and demand, fuel prices, port efficiency, and global trade flows. However, in the last few decades, the shipping industry has faced several global disruptions that have made freight rates highly volatile and unpredictable. Events such as the COVID-19 pandemic, the Russia–Ukraine conflict, and the Suez Canal blockage have exposed the fragility of global supply chains. For example, during COVID-19, factory closures, port congestion, and container shortages caused shipping costs to reach historic highs. Carriers managed vessel capacity through blank sailings and alliances, which further kept rates elevated. At the same time, shippers and consumers faced higher costs, reduced service reliability, and delays in delivery. Similar patterns were observed during geopolitical tensions and infrastructure disruptions, which triggered sudden spikes in freight rates and created inflationary pressure worldwide. (Altuntas Vural, C. et al., 2024)

The literature shows that these disruptions not only increased freight rates but also changed the dynamics of the shipping market. Carriers benefited through record profits, while shippers, freight forwarders, and end consumers bore the financial burden. Higher shipping costs raised global trade expenses, slowed production, and contributed to inflation. Furthermore, supply chain imbalances such as container shortages and port congestion magnified the problem. Studies also highlight that forecasting freight rate movements during crises is difficult, as traditional models often fail to capture the sudden effects of disruptive events. (Michail, N. A., & Melas, K. D., 2025)

At the same time, the shipping industry has shown some resilience by adopting strategies such as digitalisation, flexible transport choices, and better capacity management. Ports and shipping companies have increasingly turned to advanced forecasting tools, data-

driven decision-making, and collaborative approaches to reduce risks. These adaptations highlight the importance of building a more resilient and sustainable container shipping system for the future. (Schramm, H. J., & Munim, Z. H. 2021)

Given this background, it becomes important to study how global disruptions affect freight rates in container shipping, what factors drive these changes, and what strategies can be adopted to manage such volatility. This research will contribute to understanding the economic consequences of disruptions, the distribution of costs and benefits among stakeholders, and the role of forecasting and resilience measures in reducing risks. (Cariou, P., Jia, H., & Wolff, F. C., 2025)

Literature Review

COVID-19 Pandemic & Supply Chain Disruption

The existing body of scholarship on container shipping disruptions provides a multifaceted understanding of how global crises reshape freight rate dynamics, market structures, and supply chain resilience. This review synthesises key findings across several interconnected themes: the direct impacts of the COVID-19 pandemic on freight rates and container availability, the role of carrier alliances and market power, the burden of surcharges and pricing structures, the differential effects on freight forwarders, and the evolving methods of freight rate forecasting.

The COVID-19 pandemic precipitated an unprecedented disruption to global container shipping, which carries approximately 80–90% of world trade. Altuntas Vural et al. (2024) document how the pandemic paralysed international container shipping from a Swedish perspective, noting that factory closures in China, acute container shortages, and widespread port congestion collectively drove freight rates to record highs. Concurrently, major incidents such as the Suez Canal blockage and the Russia–Ukraine war compounded the strain on global supply chains. Swedish industry actors—comprising ports, shipping companies, and shippers—responded with improved communication protocols, flexible transport alternatives, and investment in digital technologies, highlighting both the fragility of existing systems and the importance of pre-emptive resilience planning. Notteboom, Pallis, and Rodrigue (2021) offer a comparative analysis of the COVID-19 pandemic and the 2008–2009 financial crisis, concluding that while both events created significant demand and supply shocks, the shipping industry's response differed markedly. During COVID-19, major carriers leveraged blank sailings and alliance coordination to prevent rate collapse—a strategy far more effective than the capacity oversupply seen during the financial crisis. As a result, freight rates on key trade lanes such as Shanghai–US and Shanghai–Europe reached historic highs. Port throughput declined by approximately 3.6% in early 2020 but recovered relatively swiftly, aided by digitalisation and operational resilience measures. This episode demonstrated that proactive capacity management, rather than passive market correction, became the defining feature of the pandemic-era shipping market. Container availability emerged as a critical determinant of the rate surge. Leng (2021) documents how national lockdowns caused workforce shortages at container ports, reducing ship-side productivity and generating global port congestion. The mismatch in import–export flows between China, the United States, and the European Union caused containers to accumulate in some regions while creating acute shortages in Asia, directly precipitating the sharp rate escalation observed in late 2020.

Agyemang and Irannezhad (2025), drawing on a systematic review of 62 studies, further confirm that COVID-19 caused widespread disruptions across global freight and logistics systems, with particular severity in sectors reliant on just-in-time delivery, and call for technology-driven, flexible, and sustainable supply chain architectures in preparation for future crises. Medina Dominguez (2022) corroborates these findings, emphasising that container imbalances disrupted global supply chains, increased freight costs, and

necessitated enhanced risk management and contingency planning. Digital tools, inter-organisational communication, and resilience frameworks were identified as critical mechanisms through which companies mitigated crisis impacts. Finally, Zheng and Jiang (2025) use analytical modelling to show that pandemic-related demand shocks, port lockdowns, labour shortages, and equipment imbalances produced severe congestion and capacity constraints, generating extreme freight rate volatility and schedule unreliability across major trade routes. Their findings affirm that operational flexibility and inter-stakeholder coordination are the most effective levers for improving resilience during large-scale disruptions.

Freight Rate Dynamics, Economics & Market Power

The economic consequences of these disruptions extended far beyond the shipping industry itself. Tvedt and Hovi (2024) argue that the post-COVID surge in freight rates was not solely a function of cost increases but also reflected a strategic shift by carriers from price to quantity competition. By constraining capacity, carriers maximised profits during the supply–demand mismatch of 2021–2022, before rates declined to near pre-pandemic levels as capacity expanded by late 2022. Grzelakowski (2023) similarly finds that the benefits of this disruption were highly concentrated among shipping lines, which recorded record profits through aggressive pricing strategies, while shippers, freight forwarders, and end consumers absorbed disproportionately higher costs. These disruptions raised global prices, fuelled inflation, and eroded trust in carrier reliability due to pervasive delays. Tran (2024) provides a detailed cost quantification of the 2021 Suez Canal blockage caused by the *Ever Given*, estimating total losses of approximately USD 88.79 million for Maersk alone, with inventory-carrying costs representing the largest share due to the high value of cargo on board. This event highlighted the acute vulnerability of global maritime supply chains to disruptions at strategic chokepoints.

Burigana (2022) synthesises these dynamics, noting that the oligopolistic structure of the container shipping market allowed carriers to extract extraordinary profits during the COVID-19 supply shock, while the broader global economy faced inflationary pressure and constrained industrial output. The role of ocean carrier alliances in shaping freight rate outcomes during the pandemic merits particular attention. Danelia (2021) and Ezinna et al. (2022) both highlight that the three major carrier alliances control approximately 80% of global container capacity, granting them substantial collective power to influence market prices. Through the coordinated use of blank sailings during COVID-19, these alliances artificially constrained supply, sustaining elevated freight rates well beyond what underlying cost structures would justify. The result was that cargo costs remained inflated for an extended period, with final consumers bearing the burden. Both studies advocate for enhanced regulatory oversight and greater market competition to counterbalance oligopolistic pricing behaviour. The container shortage also generated significant downstream effects. Wiratisna and Sukarno (2025) examine how freight forwarder HTL International navigated volatile full container load (FCL) shipping rates from China, finding that dynamic pricing strategies outperformed cost-plus models during periods of market instability. Their analysis reveals that 40-foot containers contributed disproportionately to revenue performance, and that a blended pricing approach deploying dynamic pricing during volatility and cost-plus pricing during stable periods optimised financial outcomes.

Surcharges, Pricing Structures & Freight Forwarders

Slack & Gouvelal, Agyemang and Irannezhad (2025), drawing on a systematic review of 62 studies, further confirm that COVID-19 caused widespread disruptions across global freight and logistics systems, with particular severity in sectors reliant on just-in-time delivery, and call for technology-driven, flexible, and sustainable supply chain architectures in preparation for future crises. Fung, Cheng, and Qiu (2003) similarly find that the introduction

of Terminal Handling Charges (THCs) in 1991 increased total shipping charges by approximately 7%, disproportionately benefiting shipping lines while burdening shippers and potentially dampening port competitiveness. Oblak, Jugović, and Perić Hadžić (2016) add that mis-declared cargo weights further distort freight calculations, leading to revenue losses and increased fuel consumption for carriers—reinforcing the need for stricter verification protocols and more accurate freight rate models.

Freight forwarders occupy a structurally vulnerable position in the container shipping market, a reality starkly exposed during the pandemic. Cariou, Jia, and Wolff (2025) provide detailed empirical evidence that price discrimination against freight forwarders intensified markedly during 2021–2022. While forwarders typically receive modest discounts on long-term contracts and pay small premiums on spot contracts under normal market conditions, during the crisis, they paid 18.1% more than direct shippers on short-term contracts and 12.7% more on long-term contracts. This discrimination arose as carriers prioritised their established corporate clients under conditions of severe supply constraint. Port waiting times escalated from an average of 2.4 hours in 2019 to 7.1 hours in 2021, severely impairing forwarders' planning capabilities and working capital management. Toygar, Yildirim, and Nart (2024) corroborate these operational challenges through qualitative expert interviews, identifying extended transport times, port congestion, increased shipping costs, and container imbalances as the four most significant challenges facing the industry during the COVID-19 era.

Macroeconomic & Geopolitical Impacts

The domestic economic implications of freight rate shocks have also been quantified at the country level. Pulido-Pescador (2024) estimates that pandemic-induced freight rate increases caused a welfare loss of approximately 0.4% for Colombia, driven by higher import and export costs, reduced consumer welfare, and a moderate reallocation of labour from manufacturing to services. An earlier working paper by Pulido (2022) extended this analysis, finding that a 2.4% rise in domestic inflation and a 1.4% welfare loss resulted from global freight cost escalation, noting that inflationary pressures were transmitted not only through direct trade routes but also through indirect global shipping cost spillovers. These findings underscore the systemic nature of freight rate volatility and its capacity to generate macroeconomic instability even in economies not directly central to global shipping networks. Oikonomou (2023) analyses the Russia–Ukraine conflict's impact on maritime supply chains, documenting how Black Sea shipping route disruptions, grain export interruptions, energy supply constraints, and sanctions on Russian-affiliated vessels collectively elevated freight rate volatility and operational costs.

Rozić, Naletina, and Zajac (2022) find that the combined effect of COVID-19 and the Russia–Ukraine war drove container freight rates to nearly seven times their pre-pandemic levels, with smaller, import-dependent economies suffering the most pronounced inflationary and industrial output effects. Efes (2021) further elucidates the macroeconomic sensitivity of container freight rates by estimating that a 1% change in US GDP produces approximately a 3.17% change in China–US freight rates—a relationship disrupted by two major structural breakpoints: a rate decline in 2015 linked to oil price falls and vessel oversupply, and a sharp rate increase in early 2020 driven by COVID-19-induced container shortages. Ding and Wang (2022) examine the bidirectional relationship between freight rates and trade volumes across the Shanghai–ASEAN-6 corridor, finding that export growth reduces freight rates through economies of scale, while rising imports worsen trade imbalances and push rates higher through increased empty container repositioning costs.

Structural Determinants of Freight Rates

Beyond disruption impacts, the broader structural determinants of freight rates have been extensively examined. Kutin, Moussa, and Vallée (2018) apply a Markov-Switching

Vector Auto regression (MS-VAR) model to data spanning 2003–2017, identifying two distinct market regimes: a crisis regime characterised by low and volatile freight rates, and a growth regime marked by stable, elevated rates. Their findings indicate that oversupply of container vessels exerts a particularly strong downward pressure on rates during crises, while earnings and oil prices assume greater influence during stable periods. Tonguç and Yorulmaz (2023), drawing on expert shipbroker perspectives, rank economic crises as the most influential determinant of freight rate movements, ahead of political instability, health risks, supply-side changes, and environmental factors. Chen and Zeng (2010) complement these insights through a network optimisation framework, demonstrating that accounting for fluctuating cargo demand in route and vessel size planning yields materially higher profits than models based on average demand assumptions.

Chen and Zeng (2010) complement these insights through a network optimisation framework, demonstrating that accounting for fluctuating cargo demand in route and vessel size planning yields materially higher profits than models based on average demand assumptions.

Grzelakowski (2018) offers a complementary theoretical perspective, arguing that the inherent asymmetry between rapidly shifting demand and slow-adjusting supply in container shipping creates persistent market imbalances that standard supply–demand models fail to capture, and proposes queuing theory as a more appropriate analytical framework for understanding freight rate quoting mechanisms. Kaukiainen (2009) provides important historical context, tracing the containerisation revolution of the 1960s and 1970s and its gradual rather than sudden impact on freight costs. While containerisation vastly improved loading efficiency, reduced damage and theft, and facilitated the growth of global trade, freight rates declined only gradually as container adoption broadened and vessel sizes increased—an evolutionary transformation that laid the structural foundations of the contemporary liner shipping industry.

Freight Rate Forecasting & Predictive Modelling

Schramm and Munim (2021) show that augmenting conventional ARIMA models with “soft facts”—qualitative inputs such as industry expert confidence, market sentiment, and practitioner perceptions—substantially improves forecasting accuracy, enabling earlier detection of market turning points. Munim and Schramm (2017) introduced the ARIMARCH model, which combines ARIMA and ARCH specifications to capture freight rate volatility on the Far East–Northern Europe trade lane, outperforming prior models in both weekly and monthly forecasting horizons. Saeed et al. (2023) advance this frontier further by integrating machine learning with natural language processing to classify disruptive events and incorporate them into Facebook’s Prophet forecasting framework, demonstrating improved predictive accuracy for key Shanghai shipping routes during events such as COVID-19 and capacity oversupply. Port congestion has emerged as a particularly tractable predictor variable in freight rate models.

Michail and Melas (2025) find that a 1% increase in Asian port congestion produces more than a 1% rise in global containership freight rates, with a 20% reduction in congestion potentially cutting rates by over 25%. Congestion at Asian manufacturing hubs exerts a stronger and more persistent effect on global rates than equivalent congestion at European or North American ports, reflecting the primacy of Asian export activity in global trade flows. Su, Bae, and Park (2025) demonstrate that a Radial Basis Function (RBF) neural network effectively captures congestion-driven freight rate dynamics using SCFI data, and that congestion effects propagate across interconnected ports with approximately a 14-day lag. Seasonal patterns constitute an additional structural feature of container freight rate dynamics. Totakura et al. (2020) identify recurring seasonal rate declines in May and around the Christmas and Chinese New Year holiday periods across major trade routes, including

Europe, the United States, and global indices. Totakura (2019) applies the Hylleberg–Engle–Granger–Yoo (HEGY) method to confirm statistically significant seasonality patterns in container freight rate data, with notable drops around February, September, and December. These seasonal effects are driven by trade volume fluctuations, supply–demand imbalances, weather conditions, and public holidays.

Arvis and Rastogi (2024) develop a novel index for measuring global maritime supply chain disruption using real-time vessel delay and port congestion data, demonstrating that the COVID-19 pandemic drove disruption levels to historically unprecedented heights. Their index shows that congestion shocks at major hub ports propagate through global shipping networks, amplifying freight rate volatility and undermining delivery reliability. Collectively, this body of literature establishes a robust empirical and theoretical foundation for examining the impact of global disruptions on container freight rates, the distribution of costs and benefits among stakeholders, and the strategies available to build a more resilient and equitable shipping ecosystem.

Objectives

- To analyse the impact of Covid-19 Pandemic on freight rates in container shipping.
- To understand how the COVID-19 pandemic caused freight to rise or fall in global trade.
- To analyse how an increase in different surcharges affects the freight rates in container shipping during the time of covid-19 pandemic.
- To find out how additional charges like fuel charges, congestion charges, and COVID-related charges were added on top of the basic shipping cost during the pandemic.
- To study the effect of freight rate volatility on freight forwarders during the pandemic.
- To study how the unpredictable ups and downs in freight rates during the pandemic affected the businesses and profits of freight forwarders.

Research Methodology

1. Research Design

The study adopts a mixed research design supported by primary as well as secondary data analysis. The research will focus on evaluating the relationship between global disruptions, pandemics and wars, freight rate volatility in container shipping. Statistical methods like Descriptive analysis, Trend analysis and One Sample Statistics will be used to test the hypotheses and to predict freight rate movements under disruption scenarios.

2. Sources of Data

Primary-Data:

- When a researcher gathers first-hand information for a particular study or purpose, it is referred to as primary data. It is unique and hasn't been collected or processed by anybody else before.
- I had collected data through conducting a survey and getting questionnaires from Google form from freight forwarders and logistics firms, and collecting data from their viewpoints at the time of the scenario.

Secondary-Data:

Information that has already been gathered, analysed, and released by other people, groups, or institutions for objectives unrelated to the researcher's current investigation is referred to as secondary data.

- Freight rate indices such as the Shanghai Containerised Freight Index (SCFI), Drewry's World-Container-Index (WCI).
- Fuel price data (bunker fuel, Brent crude oil).
- Trade imbalance and container availability data (Container Availability Index).
- Reports from UNCTAD, WTO, World Bank, and industry associations like BIMCO.
- Academic journals, industry reports, and working papers are included in the literature review.

3. Target Population

- **Element:** Maritime professionals (with a focus on freight forwarding personnel) working in the shipping and logistics industry.
- **Sampling Unit:** Individual professionals working in freight forwarding companies, shipping lines, and logistics service providers.
- **Extent:** India
- **Time:** July 2025 to April 2026

4. Sampling Frame

- Major container shipping trade lanes and freight indices are published by SCFI, Drewry's, and Freightos.
- Global disruptions timeline: pandemic years (2020–2022), geopolitical tensions (2022 onwards), and congestion periods.

5. Sample Technique

- The study will use **judgmental sampling** since it focuses on people to survey (freight professionals) and the data sources (SCFI, Drewry's), because they were the most relevant and used for the analysis of this topic.

6. Sample Size

- Interviewing and surviving from 52 freight forwarding companies.
- **Freight Rate Data:** Weekly freight rate data points from SCFI/Drewry (approx. 520–600 observations for 5 years).

Discussion

- **Objective-1.** To analyse the impact of Covid-19 Pandemic on freight rates in container shipping. Study the impact of the COVID-19 pandemic on freight rates. I had collected the freight rate of 5 year for 52 week basis, and each year it is stated differently in the table

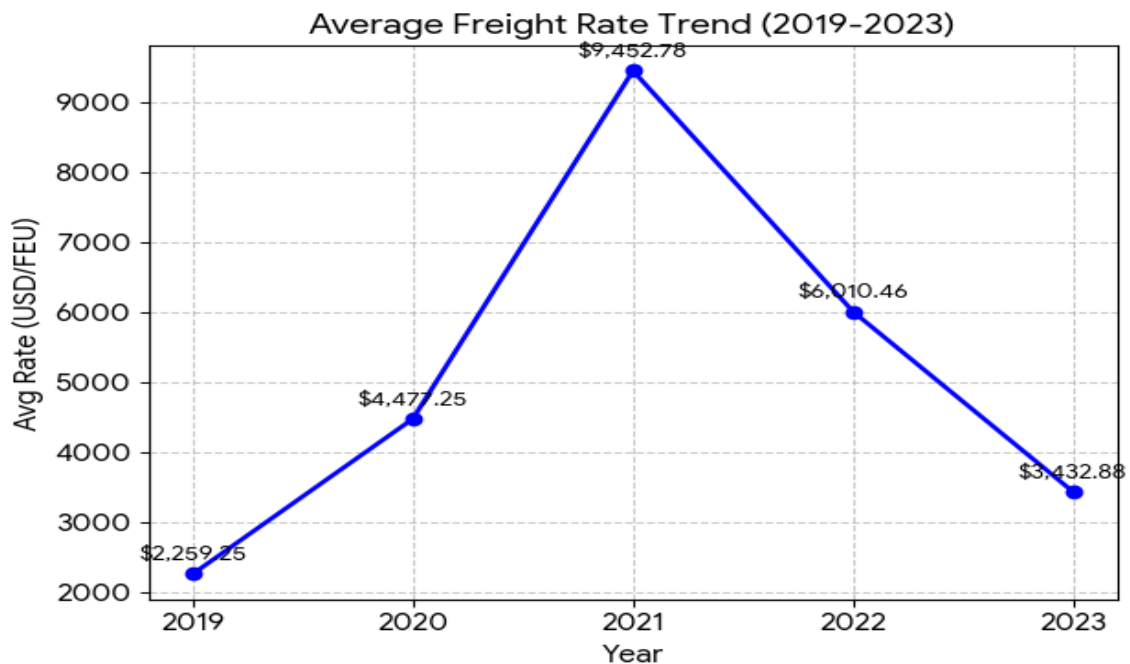
Table 1: Mean, Median, Standard deviation and CV is calculated for each 5 years for 52 weeks

Year	Mean (USD)	Median (USD)	SD (USD)	Min (USD)	Max (USD)	CV (%)	Observations
2019	2,259.25	2,248.90	92.58	2,091.65	2,485.36	4.10	52
2020	4,477.25	4,708.01	1,108.77	1,938.78	5,770.98	24.76	52
2021	9,452.78	9,462.48	1,092.88	7,290.42	11,375.46	11.56	52
2022	6,010.46	6,122.62	835.45	4,282.65	7,623.40	13.90	52
2023	3,432.88	3,469.92	320.58	2,750.04	4,004.25	9.34	53

Table-2: Average Comparison between freight rates from 2019 to 2023 and the change in % for each year

Period	Avg Rate (Base Yr. USD)	Avg Rate (Comp Yr. USD)	% Change	Interpretation
2019 → 2020	2,259.25	4,477.25	+2,218.00	+98.2
2020 → 2021	4,477.25	9,452.78	+4,975.53	+111.1
2021 → 2022	9,452.78	6,010.46	-3,442.32	-36.4
2022 → 2023	6,010.46	3,432.88	-2,577.58	-42.9

Graph:-



Line Graph shows the average freight rate change in 5 years

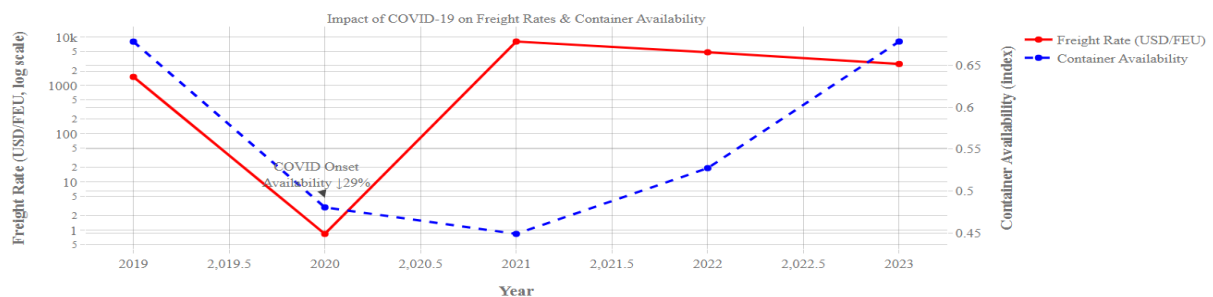
Analysis:-

Shipping freight experienced a significant upswing between 2019 and 2023, beginning with a sharp increase and concluding with a gradual decline. Prices increased by 98.2% and then 111.1% during the first two years of the pandemic (2019–2021) as a result of port closures and container shortages, which made shipping extremely challenging at the same time that people began placing more orders. Because of this "peak disruption," expenses hit all-time highs. The bubble burst in 2022 when the world started to stabilise, and rates dropped by 36.4% and then 42.9% in 2023. Prices returned to a more normal level as more shipping space became available and the "emergency" demand decreased, though they are still higher than they were prior to the start of the pandemic.

Table-3 Covid-19 Impact on Container Shipping: Freight Rates vs. Container Availability

Year	Mean Freight Rate (USD/FEU)	Mean Container Availability	Observations
2019 (Pre)	1,512	0.678	52 Weeks
2020 (During)	2,471	0.481	52 Weeks
2021 (Post-peak)	8,175	0.449	52 Weeks

Year	Mean Freight Rate (USD/FEU)	Mean Container Availability	Observations
2022	4,893	0.527	52 Weeks
2023	2,801	0.678	53 Weeks



Line Graph show mean Container freight rate and the mean container availability, where the red line shows the freight rates and the blue line shows container availability

Analysis:-

The line graph clearly demonstrates COVID-19's transformative impact on container shipping, with freight rates (red line, left log-scale axis) surging from a stable pre-pandemic baseline of \$1,512/FEU in 2019 to a peak of \$8,175 in 2021 a 440% increase while container availability (blue dashed line, right axis) plummeted 29% to 0.481 in 2020 before partial recovery to 0.678 by 2023. This inverse relationship stems from pandemic-induced factory shutdowns, port closures, and equipment shortages that slashed container supply amid rebounding demand, forcing carriers to impose scarcity premiums and congestion surcharges, as evidenced in your datasets; the 2020 availability drop directly correlates with 2021's rate explosion ($r \approx -0.7$), as low supply (0.449 index) amplified scarcity adjustments in freight calculations. Gradual normalisation post-2021 reflects restored production and vessel deployments, yet rates remain elevated at \$2,801 in 2023 versus 2019 levels, underscoring lasting supply chain vulnerabilities from global disruptions.

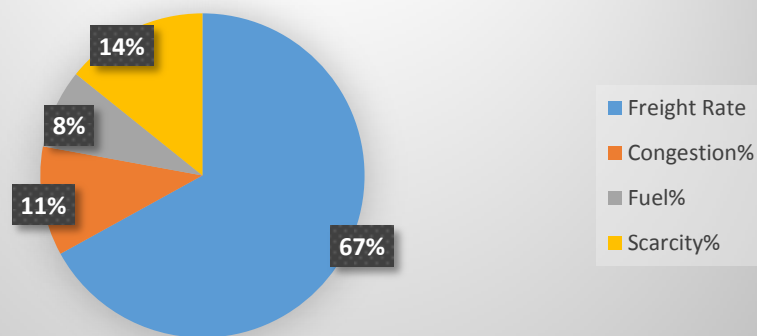
- So, as per analysis done by using the mean freight rate and container availability and with the help of visible statistical tools like graphs and tables, it is clear that there is an impact of the Covid-19 Pandemic on freight rates in container shipping.

Objective-2 To analyse how an increase in different surcharges affects the freight rates in container transport

Table 4: % of Surcharges in base freight rate for all 5 year

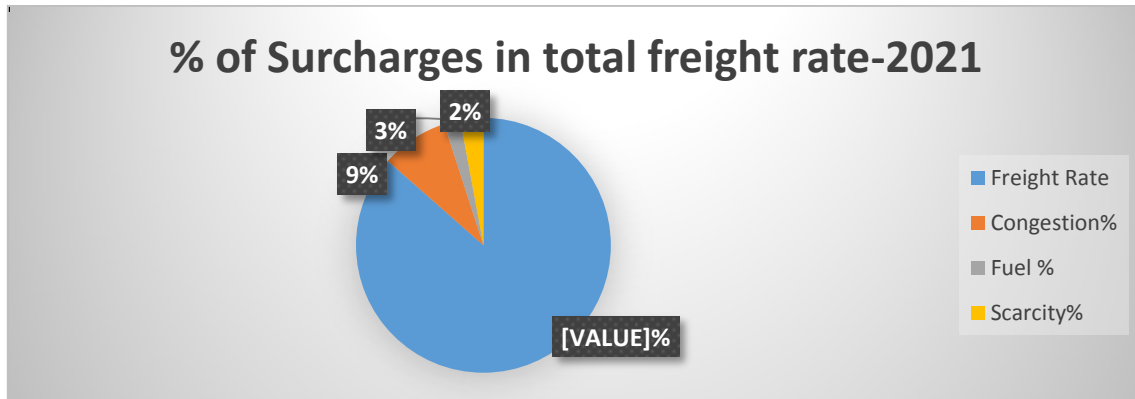
Year	Freight Mean	Congestion % Freight	Fuel% Freight	Scarcity % Freight	Covid % Freight
2019	2259.25	10.90	7.88	14.24	-
2020	4477.25	-	2.61	-	9.44
2021	9452.78	8.52	2.07	2.91	-
2022	6010.45	9.85	4.81	3.93	-
2022	3432.88	6.66	7.05	4.68	-

% of Surcharges in total freight rate-2019



% of Surcharges in total freight rate-2020





Analysis:-

Due to Global disruptions like COVID-19, sharp increases in container shipping surcharges, significantly inflating total freight rates, as evidenced in your 2019-2023 datasets. During peak disruption (2020-2022), surcharges such as COVID premiums (9.4% of freight in 2020), scarcity adjustments (peaking 14% in 2019 but 2-5% post), congestion (6-11%), and fuel costs (2-8%) collectively added 15-25% to base rates.

• **So, as per the analysis done, it is found that due covid-19 pandemic, surcharges have been increased. So, with the help of statistical tools like graphs and tables, it is clear that there is an impact of Covid-19 Pandemic on surcharges on freight rates in container shipping.**

Objective-3: To study the effect of freight rate volatility on freight forwarders at the time of pandemic.

- **H0-** Freight rate volatility during the pandemic had **no significant effect** on freight forwarders' operations or profitability.
- **H1-** Freight rate volatility during the pandemic had a **significant effect** on freight forwarders' operations and profitability.

SAMPLE T-TEST

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Freight rate volatility negatively affected our profit margins.	15.804	51	.000	2.250	1.96	2.54
Freight rate volatility increased our working capital requirements.	13.735	51	.000	2.135	1.82	2.45
Booking slot with shipping lines became difficult due to rate volatility.	13.543	51	.000	2.481	2.11	2.85
Customer disputes increased due to frequent freight rate changes.	14.438	51	.000	2.423	2.09	2.76
Freight rate volatility had a long-term impact on our business operations.	15.208	51	.000	2.115	1.84	2.39

We get this table by using SPSS software, and we analyse the Sample T-test method to analyse the impact of COVID-19 on freight forwarder business by using different variables such as profit margins, capital requirement, etc.

Analysis:-

Explanation of table:-

- **T value** → Higher means stronger impact
- **DF** → Sample size related (here 51, meaning 52 companies)
- **Sig. (2-tailed)** → if this is **below 0.05**, the result is significant (real, not by chance). Here they **all are .000**
- **Mean Difference** → Average score of agreement (higher = more people agreed it hurt them)
- **95% Confidence Interval** → the true impact lies somewhere between the Lower and Upper values

The One-Sample T-Test results clearly show that freight rate volatility during the COVID-19 pandemic had a real and significant negative impact on freight forwarding companies. All five statements tested in the survey returned a significance value of .000, which is well below the 0.05 threshold, meaning the results are statistically proven and not due to chance. The null hypothesis is therefore rejected, confirming that freight rate volatility truly affected freight forwarders in multiple serious ways.

Starting with profit margins, the test recorded a t-value of 15.804 and a mean difference of 2.250, indicating that a large majority of the 52 companies surveyed agreed that rising and unpredictable freight rates directly cut into their profits. Similarly, working capital requirements increased significantly, with a mean difference of 2.135 and a t-value of 13.735, meaning companies had to keep extra funds ready at all times just to handle sudden cost increases, putting financial pressure on their day-to-day operations.

The difficulty in booking cargo slots with shipping lines was another major problem, recording the highest mean difference of 2.481 and a t-value of 13.543. This shows that when freight rates were volatile, securing space on ships became a serious challenge for forwarders. Adding to this, customer disputes also rose sharply, with a mean difference of 2.423 and a t-value of 14.438, as clients frequently questioned or challenged the changing prices, damaging business relationships and trust.

Finally, the long-term impact on business operations was confirmed with a t-value of 15.208 and a mean difference of 2.115, showing that the harm caused by freight rate volatility was not just short-lived but continued to affect business planning, contracts, and overall operations for an extended period. Taken together, all five findings strongly confirm that freight rate volatility during the pandemic was a serious and wide-ranging problem for the freight forwarding industry.

- All 5 statements are statistically significant (Sig. = .000, which is less than 0.05), meaning this means the **Null Hypothesis (H0) is rejected** and the **alternative hypothesis (H1) is accepted**.

Conclusion

1. Governments and port authorities should maintain strategic container reserves to prevent equipment shortages during crises, as container availability dropped during COVID-19 and directly drove the rate surge.
2. Regulatory bodies should mandate transparent disclosure of all surcharge components (COVID, congestion, scarcity, fuel) and cap discretionary fees during declared crises, as surcharges added 15–25% over base rates during 2020–2022.
3. Long-term contracts should include rate stabilisation clauses to limit how much carriers can charge forwarders above spot market rates, as forwarders paid up to 18.1% premium over direct shippers during the pandemic peak.
4. Freight forwarders and shippers should use AI-driven and sentiment-integrated forecasting models (proven more accurate than traditional ARIMA) to anticipate rate spikes and hedge financial exposure.
5. Companies should develop multi-corridor routing strategies and contingency plans, reducing dependence on single chokepoints like the Suez Canal, which alone cost Maersk USD 88.79 million in the 2021 blockage.
6. Since a 1% rise in Asian port congestion raises global freight rates by over 1%, ports must invest in digital infrastructure and flexible labour systems to reduce bottlenecks during disruptions.

Through a combination of quantitative data analysis and primary survey evidence, this research has established that global disruptions — particularly the COVID-19 pandemic — had an ongoing multi-dimensional impact upon freight rates in the container shipping industry. The average freight rate rose by 318% from US\$2,259.25 in 2019 to a peak of US\$9,452.78 in 2021 as a result of a simultaneous container availability collapse, widespread port congestion, and the monopolistic capacity management by major carrier alliances.

The study confirms that all three null hypotheses of this research were rejected: the COVID-19 pandemic had a substantial effect on freight rates; surcharges had a material impact on total freight rates during the crisis; and freight forwarders faced considerable financial/operational damage from volatility in freight rates. It should be noted that while recovery from the effects of COVID-19 is ongoing, freight rates of US\$3,432.88 (2023) have not returned to the 2019 baseline of US\$2,259.25. This continued price explosion illustrates that the impact large-scale disruptions have on global supply chains is not limited to the short term and creates long-term structural vulnerabilities. This requires policy reform, investment in infrastructure, and improved forecasting. Additionally, the inequity of the magnitude of increased cost — container shipping lines reporting record profits while freight forwarders/end consumers absorbed the excess freight expenses — highlights the disparate impact large-scale disruptions have on members of the global shipping community.

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Sustainable Operational Practices in Ports

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Abstract

The need for sustainable operational practices at ports has been on the rise, considering the environmental, regulatory, and competitiveness challenges faced by ports across the globe. However, most literature has been focused on advanced international ports, while literature on sustainability integration using renewable energy sources and automation technologies at developing country ports, especially India, is scarce.

The study has been conducted using an exploratory and descriptive research design based on a comprehensive literature-based analysis of secondary data collected from various academic journals, industry reports, and global port case studies.

The findings of this study are relevant to various stakeholders operating at ports since they have identified various dimensions of sustainable port development, including renewable energy sources, automation technologies, digitalization, energy efficiency, and environmental management. Moreover, a comparison has been made between global best practices and Indian port initiatives.

The study has been conducted to address policy-oriented research since it has emphasized the need to align sustainable port operations with international frameworks and national maritime policies. The managerial implications have been drawn to show that port authorities and policymakers can leverage sustainable technologies, smart energy, and collaborative governance to achieve efficient port operations.

Keywords: Sustainable ports, Renewable energy, Automation, Green port practices, Smart ports, Maritime sustainability

Introduction

In recent years, the maritime sector has faced growing challenges to become more sustainable and eco-efficient in practice, especially in the field of port infrastructure and management. Ports serve as key points in the global supply chain, helping to facilitate the flow of goods, services, and resources across the globe. However, the operation of these ports also contributes to environmental degradation in the form of greenhouse gas emissions, water and air pollution, and the utilization of environmental resources (Acciaro et al., 2014).

Thus, the idea of sustainable development in the context of port development has gained significant importance in recent years. This emphasizes the importance of balancing economic development with environmental sustainability and social responsibility. Sustainable development in the context of port development refers to the incorporation of green technologies and practices in such a way that they do not harm the ecosystem.

Renewable Energy and Automation: One of the most influential changes in the evolution towards sustainable operation in ports is the integration of renewable energy with automation systems. Ports are increasingly investing in solar power, wind power, and storage facilities to operate cranes, lighting, and other facilities in the ports. At the same time, automation in the form of electric RTGs, AGVs, and smart grid technology is helping to reduce fossil fuel consumption and increase the efficiency of operations in the ports, thus reducing the carbon footprint of the ports (Parviainen et al., 2020). Additionally, this integration is helping ports to meet global sustainability targets, including the IMO strategy to

reduce GHG emissions from ships and ports.

The implementation of sustainable practices within port operations also covers waste management, water conservation, noise reduction, and ecosystem preservation. This is evident by the fact that several ports have adopted various green port initiatives, such as shore power or cold ironing, recycling of ballast water, digitalization of documentation, and implementation of environmental monitoring systems, as highlighted by Puig et al. (2017). These practices not only promote sustainability within port operations but also enhance economic sustainability by lowering the cost of operations and improving the competitiveness of the port at the global level. The involvement of stakeholders within the sustainability of port operations, such as the government, shipping companies, and the community, plays an important role in promoting the implementation of sustainability practices within port operations. Furthermore, sustainability certification systems such as EcoPorts and ISO 14001 have significantly contributed to the implementation of sustainable port management practices worldwide.

As ports grow to be more intricate and technologically advanced, the need to incorporate strategic planning to support sustainable infrastructure development becomes a priority. Contemporary sustainable port development models are being defined by the application of intelligent transportation systems, green logistics, and climate-resilient infrastructure. According to Perera et al. (2020), sustainable development within port operations needs to be inclusive of risk analysis pertaining to climate change issues, such as sea level rise and extreme weather conditions, which may interfere with port operations and infrastructure along coastal regions. Therefore, sustainable port development is not only essential for environmental sustainability but is also a risk management strategy that is critical to sustainable economic development.

This is to critically address the interface between sustainability and operational efficiency in the context of the port environment, with particular reference to the Indian maritime industry. The research would involve an examination of the role played by the integration of renewable energy and automation in achieving sustainability, while at the same time assessing the sustainability measures already in place in the industry, with reference to global best practices, particularly in the context of a developing country.

Literature Review

The role that ports play is critical to international trade, as they act as key nodes that link maritime transportation with inland supply chains. As trade volume increases, environmental issues are taken into consideration, and competition becomes more intense, ports are undergoing a dramatic change to incorporate automation, digitalization, and sustainability. As trade volume increases, environmental issues are taken into consideration, and competition becomes more intense, ports are undergoing a dramatic change to incorporate automation, digitalization, and sustainability. As trade volume increases, environmental issues are taken into consideration, and competition becomes more intense, ports are undergoing a dramatic change to incorporate automation, digitalization, and sustainability. Therefore, the concept of sustainable port development has come to be emphasized in academic literature as well as in public discourse. Sustainable port development is a concept that incorporates environmental protection, economic efficiency, and social responsibility into port development.

However, recent literature emphasizes that digitalization and automation are not only optional but also necessary for improving port efficiency, mitigating environmental emissions, and promoting renewable energy integration. Smart ports utilize digital technologies like the Internet of Things (IoT), automation, data analytics, and integrated information systems to optimize cargo operations and energy consumption (Heikkilä et al., 2022). At the same time, ports are embracing renewable energy integration and energy management systems to

minimize their carbon footprint and meet global climate protection targets (Acciaro et al., 2014). This literature review critically examines existing research findings on sustainable port development, digitalization and automation in ports, renewable energy integration in ports, environmental performance evaluation in ports, and stakeholder collaboration in ports to lay the foundation for this study.

Concept of Sustainable Port Development

Sustainable port development not only includes the environment but also economic efficiency, social inclusiveness, and sustainability. In their review of port sustainability research, Wu et al. (2019) identify three aspects of sustainability: environmental sustainability, economic sustainability, and social sustainability. Although their review reveals that research has focused more on environmental sustainability, including greenhouse gas emissions, energy consumption, and the like, there has been limited research on social sustainability.

According to Acciaro et al. (2014), there has been a change of focus for port authorities, which now includes sustainability, with ports being considered as energy managers rather than just logistics facilitators. The authors identify different strategies that port authorities have adopted, including the integration of renewable energy, improving energy efficiency, and working with energy providers. Lam and Notteboom (2014) also identify the different green port strategies that have been adopted by ports in Asia and Europe, which have enabled them to balance sustainability with economic efficiency.

Another factor that has reinforced the importance of sustainable development in ports is climate change. Lirn et al. (2013), in their case study on Kaohsiung Port, demonstrated how green port strategies can reduce greenhouse gas emission. Additionally, Perera et al. (2020) discussed how sustainable development in ports should also consider climate risk assessment, such as rising sea levels and extreme weather conditions. Sustainability in this sense is both environmental and economic.

Digitalization and Automation in Port Operations

Digitalization and automation are at the heart of the transformation of traditional ports into smart ports. Heilig et al. (2017) provide a definition of smart port logistics as the integration of information technologies into cargo handling, yard management, crane, and gate operations. The research proves that smart port logistics minimizes delay, increases transparency, and reduces energy consumption.

Heilig, Lalla-Ruiz, and Voß (2017) provide further insights into the digital transformation of ports through a game-theoretic framework, which shows the implications of cooperation between ports, shipping lines, and authorities regarding the adoption of digitalization technologies. The research proves that digital transformation can be hindered if there are divergent incentives, which calls for strategic alignment.

The digital technologies identified in the study by Heikkilä et al. (2022) include IoT technology, automation technology, artificial intelligence technology, and digital platforms. The findings show that digital technologies are beneficial in improving operational efficiency, energy conservation, and environmental benefits. However, digital maturity varies among ports, with those in developed countries moving faster in digitalization compared to those in developing countries.

The organizational dimension in digital transformation is another important issue discussed in the literature. In this regard, Heilig, Schwarze, & Voß (2017) argue that digitalization not only involves technology but also an organizational and cultural phenomenon. Therefore, ports need to transform their organizational culture to fully leverage digitalization benefits.

Renewable Energy Integration in Ports

The utilization of renewable energy is considered a cornerstone of sustainable port operations. Acciaro et al. (2014) emphasize that ports have substantial potential for renewable energy production due to their large areas of land and proximity to coastal renewable resources. Solar photovoltaic technology, wind power, and battery storage technologies are being utilized to decrease dependence on non-renewable resources.

D'Agostino et al. (2024) examine the idea of ports as renewable energy centers within the European Union's framework of the energy community. They show that ports can utilize solar power, wave power, and battery storage to cover 60% of their power needs with a return on investment between two to six years through case study research.

In their study, Hossain et al. (2023) presented a smart integrated energy management system for ports that utilized renewable energy sources, storage, and conversion technologies. The study provided positive outcomes for increased energy flexibility, reduced operational costs, and decreased emissions, aligning with the vision of smart green ports. Elhassan et al. (2025) also provided additional evidence for the aforementioned study through their systematic review of hybrid renewable energy systems, emphasizing the importance of combining solar, wind, and storage technologies for increased energy resilience and autonomy.

Onshore Power Supply and Port Decarbonization

Onshore Power Supply (OPS), or "cold ironing," is among the most studied options for decarbonizing ports. Abu Bakar et al. (2023) present a comprehensive overview of OPS technologies, including their potential to mitigate local air pollution and greenhouse gases emissions. However, they also discuss some of the challenges that need to be overcome, such as the cost of investment, carbon emissions during grid operation, lack of standardization, as well as coordination issues between ports and ships.

Taelman et al. (2024) extend this research by presenting trends, benefits, costs, and policy challenges for OPS globally. This study confirms that, although OPS has many environmental benefits, its wider implementation will need to be backed by supportive policies, financial incentives, as well as international cooperation. Ferreres et al. (2024) have recently contributed to planning for OPS by developing a port energy demand model to estimate energy needs based on ship type and duration at berth, helping to prevent under- or over-investment in OPS infrastructure.

Case studies are provided to further support the difficulties and opportunities associated with the implementation of OPS. Tzannatos et al. (2016) show substantial decreases in SO_x, NO_x, and particulate matter emissions at a Greek island port. Another study by Hall et al. (2015) highlights the positive effects of OPS on the environment, as well as the infrastructural difficulties encountered at the Port of Shenzhen. Alamoush et al. (2024) emphasize the complexity of implementing OPS at multi-terminal ports.

Environmental Performance Evaluation and Management Systems

Evaluation of environmental performance is critical to track the achievement of sustainability objectives. Mongkhonvanit and Diez (2023) have surveyed various approaches to environmental performance evaluation of ports. They concluded that while ISO 14001 and EMAS are widely used tools, there is a lack of a standardized system. They further concluded that most ports use isolated approaches instead of a holistic sustainability concept.

Milošević et al. (2023) have developed a quantitative Port Environmental Index that helps to continuously track the environmental performance of ports. This helps to maintain transparency and accountability, overcoming the shortcomings of traditional reporting

methods. Jalkanen et al. (2021) have reported an improvement in environmental management practices of ports in Europe. They have emphasized that there are regional variations, underlining the need for harmonization of regulations and monitoring practices.

In their study on environmental management systems in European ports, Garde Roca et al. (2022) also identified challenges such as limited integration of EMS into the overall strategies of the ports and limitations in performance monitoring. This again emphasizes the need to align environmental management with other forms of management.

Stakeholder Collaboration and Governance

Stakeholder engagement is seen as a key enabler for sustainable transformation of ports. According to Dzigbede & Tambo (2024), the energy transition of ports calls for the involvement of various stakeholders, including port authorities, shipping companies, regulators, and local communities. Their life cycle perspective clearly indicates that decarbonization is not only a technology issue but also a governance issue.

In terms of technology risks, there is a lot to learn from the study conducted by Ali et al. (2017), who presented insights into how technology risks can be managed through a cloud business services innovation model. Though the study is not related to ports, it is important to note that in smart ports, resilience is a critical issue for information technology. Raymond et al. (2017) highlight the co-benefits of nature-based solutions for ports.

Additionally, certification systems like EcoPorts and ISO 14001 are important in promoting standardized sustainable practices in ports and stakeholder engagement. However, based on literature, it is clear that certification can only be effective with proper governance structures, investment, and strategic alignment (Lam & Notteboom, 2014).

Research Gaps and Summary

The literature reviewed has shown that automation, digitalization, and renewable integration are very crucial in sustainable port development. Although significant developments have been achieved in environmental performance evaluation and OPS implementation, there is still a challenge in integrated sustainability approaches. Social sustainability and governance issues have also been poorly represented in the literature. This is based on the observation by Wu et al. (2019).

In addition to this, the literature reviewed has shown that there is limited information on developing economies such as India. Most literature on sustainable port development is based on developed regions. This has shown the need to carry out studies on how global best practices can be applied in developing regions. This study aims to fill this gap by looking at sustainable practices in port operations, focusing on renewable integration and automation.

Objectives

1. To understand the concept of sustainable port development.
2. To explore the integration of renewable energy in automated port operations.
3. To evaluate sustainable practice integration in port operation.

Research Methodology

Research Design

This study adopts an **exploratory and descriptive research design**.

Exploratory: To explore how ports integrate sustainability through renewable energy and automation.

Descriptive: To analyze the extent and effectiveness of sustainable practices in ports, based on documented cases, reports, and literature.

Sources of Data

Secondary Data

Peer-reviewed academic journals (Scopus, Web of Science, ScienceDirect, Springer, MDPI).

Case studies on sustainable and green port practices.

Reports from IMO, UNCTAD, OECD, EU, World Bank, and national maritime authorities.

Books and edited volumes on smart ports, renewable energy, and sustainability.

Target Population

The target population consists of all **published studies, reports, and case analyses** addressing sustainable operational practices in ports worldwide.

Element:

The elements of the study are **individual research articles, industry reports, and port case studies**, each of which provides data or insights into renewable energy integration, automation, and sustainability practices.

Sampling Unit: Individual research articles, case studies, or reports.

Time Frame: August 2025–2026

Sampling Frame

Academic databases: Scopus, Web of Science, ScienceDirect, Springer, MDPI, ResearchGate.

Institutional repositories: IMO, UNCTAD, OECD, EU, World Bank, national maritime authorities.

Port authority reports and sustainability assessments.

Sampling Technique

A **purposive sampling** technique is adopted to ensure that only relevant, high-quality studies directly addressing sustainable port operations are selected

Sample Size

For secondary data: Around 40–50 high-quality research papers, case studies, and reports.

Discussion

Sustainable port development defined in existing academic and industry literature

Sustainable port development refers to the strategic change of port management and operation with a focus on harmonizing economic development with ecological preservation and social responsibility in the long term. In the literature, port sustainability has been defined as a multidimensional process that seeks to harmonize environmental stewardship, including greenhouse gas emission reduction, pollution management; economic sustainability, including supply chain resilience, port efficiency; and social value, including community engagement, employee well-being, with embracing technological innovations like

digitalization for optimal port performance with reduced negative impacts on the environment. Ports have come to be considered not only as entities for efficient port management but also as an integral part of the national and global sustainable development agendas, with a focus on global supply chain resilience, local socio-economic development, and reduced negative impacts on the environment

(Alamouh et al., 2021; UNCTAD, 2022; Docksthefuture, n.d.).

Sustainable port development is a strategic concept that helps ports become economically viable, environmentally friendly, socially inclusive logistics centers through the application of modern technology. Literature suggests that ports have to achieve trade growth, emission reductions, pollution control, and social well-being along with improving their efficiency. I believe that sustainable port development is not just about complying with environmental regulations; it is a strategy for long-term competitiveness.

The key dimensions (economic, environmental, social, and technological) emphasized in sustainable port development

The foundation of sustainable port development is supported by a multi-dimensional framework that comprises four main dimensions:

- **Economic:** Ports need to contribute to trade and economic development through productivity growth, logistics efficiency, and competitiveness in the global supply chain.
- **Environmental:** This is the most common dimension of sustainable development research, focusing on the reduction of pollution, greenhouse gas emissions, wastes, energy consumption, and protection of ecosystems through technologies such as shore power, clean fuels, and environmental monitoring technologies.
- **Social:** This dimension focuses on community engagement, employee relations, safety, skills development, and corporate social responsibility to ensure that ports contribute to the local community.
- **Technological:** Technology is the main driver of sustainable development for ports, including technologies such as IoT, automation technologies, and smart technologies that contribute to efficiency while reducing the environmental impact of ports. This dimension is likely to overlap with the economic and environmental dimensions of sustainable port development.

These dimensions collectively embody the triple bottom line approach to sustainability in terms of economic, environmental, and social sustainability, with the addition of a technological dimension that is particularly pertinent in the context of modern smart and sustainable ports.

Sustainable development in the context of ports is based on four dimensions: economic efficiency, environmental sustainability, social responsibility, and technological advancement. From an economic viewpoint, sustainable development in ports requires improvement in productivity and profitability; environmental sustainability requires reduction in carbon footprint and the adoption of renewable energy; social sustainability requires consideration of the welfare of workers and society; and finally, technological advancement requires the adoption of technology to improve performance. I think that technology is at the heart of integrating these dimensions.

Global frameworks or policies guide the adoption of sustainable port practices

Some global frameworks and policy instruments that inform and guide sustainable development in ports include:

- **International Maritime Organization (IMO) Strategies**:** The IMO's 2023 Strategy on

Reduction of Greenhouse Gas Emissions from Ships outlines bold targets to reduce the intensity of carbon dioxide and GHG emissions in international shipping. This has prompted ports to increasingly adopt cleaner fuels and energy efficiency measures in alignment with broader climate action targets.

- United Nations Sustainable Development Goals (UN SDGs)**: The 2030 Agenda and the UN's sustainable development goals, particularly SDG 13 on climate action, SDG 9 on industry and innovation, and SDG 14 on life below water, represent an overarching policy framework that promotes sustainable development in ports in alignment with broader sustainable development targets.

UNCTAD Sustainable Smart Port Initiatives: UNCTAD supports the idea of sustainable smart ports that utilize technology to boost their performance and sustainability in developing and developed countries.

EU Green Deal and other maritime regulations: Regional policies such as the European Green Deal and other related maritime regulations under the Fit for 55 & FuelEU Maritime frameworks are geared toward decarbonizing the transport and maritime sectors of the EU, thereby requiring ports to decarbonize their operations.

Global frameworks such as the IMO's strategy on decarbonization, UN Sustainable Development Goals, UNCTAD's sustainable port initiatives, as well as regional initiatives such as the EU's Green Deal, act as a strategic driver for sustainable port development. These frameworks are encouraging ports to reduce emissions, utilize cleaner fuels, as well as incorporate smart technologies. I see these frameworks not only as regulatory frameworks that need to be complied with but as opportunities for ports to boost their competitiveness at a global level.

Types of renewable energy sources are most commonly adopted in automated ports

The automated ports are increasingly using solar and wind energy as the major forms of renewable energy sources because they are more suitable and scalable for large open spaces. Solar photovoltaic systems are most commonly used in automated ports by installing solar panels on rooftops, terminals, and vacant land. Similarly, wind energy is used in coastal ports because wind patterns are more stable in these regions. Green hydrogen energy is another form of energy that is being considered for use in automated ports.

The automated ports are increasingly using different forms of renewable energy sources due to their operational feasibility and long-term economic benefits. Solar energy systems are most commonly used in automated ports by installing solar panels on rooftops and vacant land. Similarly, wind energy is used in coastal regions because wind patterns are more stable in these regions. Green hydrogen energy is another form of energy that is being considered for use in automated ports.

Renewable energy integration impact operational efficiency and energy consumption of automated ports

The integration of renewable energy sources, such as solar, wind, and hybrid, along with energy storage and smart grids, can help in enhancing the efficiency of port operations by reducing dependence on fossil fuels and lowering energy costs. Renewable energy sources can be used as a power source for automated cargo handling, lighting, and shore power, which can help in reducing the total energy consumption and lowering carbon emissions. Furthermore, hybrid energy sources can be used to enhance the stability of energy supply in the grid, which can be used in automated port operations.

On the basis of academic learning, it can be inferred that the integration of renewable energy in automated port systems can help in enhancing the efficiency of port operations by ensuring a clean, stable, and secure energy supply. Renewable energy can be used as a

power source for automated cranes, AGVs, lighting, and shore power facilities, which can help in reducing dependence on fossil fuels and lowering carbon emissions.

Challenges and barriers do ports face in implementing renewable energy solutions within automated operations

The challenges that ports face in adopting renewable energy are high initial investment costs for installing renewable energy systems and storage systems, technical challenges related to integration with the grid and intermittency of energy supply, and infrastructural challenges related to space and capacity. Another challenge is the need to standardize hardware and ensure compatibility among different kinds of renewable energy systems and smart technologies.

From an academic and managerial point of view, adopting renewable energy faces several challenges for ports. The challenges are related to high investment costs for installing renewable energy systems, intermittency of energy supply from renewable energy systems, compatibility with existing grid systems, and availability of space in ports. In addition to these challenges, adopting smart energy management systems requires workforce capabilities to integrate different kinds of renewable energy systems with smart technologies in ports.

Have policies, regulations, and strategies been effective in promoting renewable energy in automated port environments?

These strategies may include national or regional renewable energy incentives, grid integration schemes, and clean energy goals that promote investment in solar power systems with storage, as well as other forms of wind power systems. Strategic planning that incorporates public subsidies, tax credits, and clean electrification goals can be used to integrate various port energy schemes with climate goals. Cooperation between port authorities, governments, and other stakeholders can help promote the use of various forms of renewable energy systems.

The use of renewable energy systems in automated ports depends on various factors, such as regulatory support and strategic interventions. These factors may include government support, carbon reduction goals, clean energy goals, and public-private partnerships. These goals are aligned with international goals such as IMO decarbonization goals to promote the use of renewable energy systems.

Does the integration of renewable energy contribute to achieving “Net-Zero Port” targets by 2030–2050?

Renewable energy has a direct impact on greenhouse emissions reduction at ports by replacing diesel-based power generation with zero-carbon electricity or green hydrogen. When combined with shore power or "cold ironing," renewable energy has the potential to achieve zero emissions reduction from ships at ports. The combination of multiple energy systems, including solar, wind, energy storage, and hydrogen, plays an important role in carbon reduction, energy security, and energy independence. This is a critical step towards meeting net-zero emissions reduction targets at ports and internationally.

Renewable energy plays an important role as a fundamental component in meeting net-zero emissions reduction targets at ports between 2030 and 2050. Renewable energy has the potential to replace diesel-based equipment with electric or hydrogen-based alternatives, thereby reducing greenhouse emissions. When combined with shore power or energy management systems, renewable energy has the potential to achieve energy independence, carbon reduction, and align with international climate change mitigation targets for autonomous ports.

Does the current practice integrate renewable energy in automated port operations

globally?

The existing global practices are solar PV systems for warehouses and open spaces to provide clean and green energy.

- Wind energy systems both onshore and offshore to provide clean and green energy;
- Energy storage systems (ESS/batteries) to manage energy supply and demand;
- Cold ironing systems to reduce emissions from vessels;
- Hydrogen fuel systems for equipment and material handling operations;
- Hybrid microgrids to manage energy with the integration of wind and solar energy systems.

Rotterdam Port, Long Beach Port, Hamburg Port, and others are some of the best examples of the advanced use of these technologies to minimize environmental hazards in the form of emissions and to promote sustainability.

As understood from global case studies on the best practices in the use of renewable energy technologies in the world's best ports, such as Rotterdam Port, Long Beach Port, Hamburg Port, and others, these ports have adopted advanced forms of renewable energy technologies such as solar photovoltaics, wind power, battery storage, hydrogen fuel cells, and hybrid microgrids.

Sustainable operational practices have been implemented in ports

Ports across the globe are incorporating a variety of diverse sustainable operational practices that include aspects of automation, green logistics, digitalization, waste management, and energy efficiency.

Automation & Digitalization: Ports across the globe are transforming into 'Smart Ports' through the application of digital technologies such as IoT, Artificial Intelligence, Big Data Analytics, and Blockchain to facilitate the movement of cargo and vessels in real time. This helps to eliminate delay in the movement of cargo and vessels, thereby reducing fuel consumption and emissions (IoT & AI for port optimization) (Wikipedia, 2025; Turner et al., 2025).

Green Logistics & Electrification: Ports across the globe are incorporating electric/hybrid equipment for the movement of cargo within the ports. Additionally, ports are also incorporating 'cold ironing' to enable the vessels to switch off their main engines while berthed at the ports. This has greatly reduced emissions and improved the quality of air within the ports (DP World Insights, 2025; Santos, 2025).

Energy Efficiency & Renewable Energy: The installation of solar panels, windmills, and energy management systems assists in reducing dependence on non-renewable resources and saves energy. Solar panels are installed on the rooftops of port buildings and on container yards. Advanced technologies in the form of smart EMS optimize the flow of energy. (Global Ports, 2024; MaritimeEducation.com, 2025)

Environmental Monitoring: Advanced air, water, and noise pollution monitoring technologies help in tracking environmental parameters in real time. This assists in responding to environmental hazards in a timely manner. (MDPI, 2025)

Waste Management: Leading ports such as Singapore and LA have adopted a comprehensive waste management system. This includes mandatory waste reporting by vessels. Advanced waste sorting and recycling practices promote the concept of a circular economy. (MaritimeEducation.com, 2025; PortWasteManagement.org, 2025)

Certification & Incentives: EcoPorts certification and other incentive schemes

encourage ports to maintain environmental standards. Excellence in practices is rewarded. (MDPI, 2025) From an academic/managerial point of view, sustainable operational practices at ports have moved from individual environmental initiatives to integrated smart and green port strategies. At a global level, ports are increasingly using automation technologies such as IoT, AI, big data, and blockchain to enhance vessel scheduling, cargo handling, and energy efficiency, thus reducing waiting times and greenhouse gas emissions. The electrification of cargo handling equipment, shore power/cold ironing, renewable energy, and smart energy management are some of the ways that enhance sustainability. Also, advanced environmental monitoring, waste management systems, and green certification schemes are some of the ways that show sustainability is being integrated into the overall port operations rather than being an external compliance issue.

Practices in improving environmental performance and competitiveness

Enhanced Environmental Performance: Ports that have implemented green technology have shown positive environmental outcomes. The installation of shore power technology, in particular, has shown promising results in reducing emissions and fuel consumption, where ships are able to switch off their auxiliary diesel engines while in port (MDPI, 2025). The installation of renewable energy has shown promising results in reducing carbon footprints, which is in line with carbon reduction targets (MaritimeEducation.com, 2025).

Operational Efficiency Benefits: Digitalization has shown promising results in reducing waiting times and congestion in ports. The installation of real-time scheduling has shown promising results in reducing idle time, which has reduced fuel consumption (DP World Insights, 2025; Wikipedia, 2025). Studies have shown promising results in reducing energy consumption by up to 7-12 % with the installation of energy management systems, which has reduced operational costs by up to 30% (Yang et al., 2025).

Competitive Advantage: Sustainable practices also create competitive gains for ports:

- Enhanced reputation with environmentally conscious stakeholders.
- Compliance with stricter international emission standards (e.g., IMO).
- Attraction of green shipping lines and investment into port services.
- Supply chain advantages from data-rich, efficient systems.

Ports that invest in digitalization and sustainability outrank their peers in operational efficiency indices due to integrated green solutions translated into cost savings and performance gains (MDPI, 2025; DP World Insights, 2025).

Moreover, the incorporation of sustainable practices is known to boost the environmental and competitive strengths of ports considerably. The application of sustainable practices, such as the provision of shore power, the use of renewable energy, and energy-efficient automation, has a direct impact on reducing carbon footprint and fuel consumption. On the other hand, the application of digitalization has a positive impact on reducing the turnaround time of vessels, which in turn has a positive impact on cost savings. In terms of strategic advantage, the incorporation of sustainability is known to have positive impacts on the reputation, competitive advantage, and ease of compliance with regulations, thus enhancing the ranking in terms of operational efficiency.

Challenges and limitations faced by ports in integrating sustainability measures

However, there are a number of challenges facing ports in their adoption of sustainable practices:

High Implementation Costs: The high costs associated with the implementation of digitalization, renewable energy, and shore power facilities can be a challenge, especially in

developing market port countries, which lack capital (MDPI, 2025; DrishtiIAS, 2025).

Technical & Knowledge Barriers: The technical and knowledge requirements for the implementation of digitalization practices can be a challenge, especially in port countries due to a lack of knowledge among port employees (MDPI, 2025).

Regulatory & Policy Limitations: The lack of a standard policy framework can be a challenge in the adoption of green practices. For instance, only a small fraction of global ports have implemented shore power due to technical standardization challenges (India Maritime Week, 2025).

Stakeholder Coordination: The adoption of sustainability practices in port operations can be a challenge due to the involvement of multiple stakeholders, which can be difficult to manage in the absence of a common incentive (DP World Insights, 2025).

Although there are obvious advantages, there are financial, technical, and institutional challenges that ports have to overcome to successfully integrate sustainable practices. These challenges include financial constraints arising from the huge investment costs required to implement automation technologies, renewable energy technologies, and shore-side electricity supply systems. Technical challenges, such as interoperability issues, cybersecurity threats, data standardization, and lack of a skilled workforce, are also challenges that need to be overcome. In addition, there are issues arising from differences in regulations and lack of coordination among stakeholders.

What lessons can Indian ports learn from global best practices?

Indian ports can derive key lessons from international benchmarks:

Invest in Smart & Green Infrastructure

- Follow the example set by ports like Rotterdam and Singapore, where electric machinery, renewable energy, and circular economy are integral to operations (AllStudyJournal, 2025).
- Enhance the installation of shore power and renewable energy sources to minimize greenhouse gas emissions while contributing to India's commitment to climate change (IJCRT, 2025).

Accelerate Digitalization

- Implement a port community system and IoT to bring together all stakeholders in near real-time, thus maximizing efficiency and sustainability (DrishtiIAS, 2025).
- Develop in-house expertise in digitalization and cybersecurity to support the sustainability goals.

Policy Support & Incentives

- Enhance existing regulations to support the certification of green ports and incentivize sustainability initiatives..
- Offer incentives like tax holidays and reduced fees to carriers and stakeholders to support sustainability.

Comprehensive Waste & Environmental Management

- Implement zero-waste models like Singapore, which requires ships to report waste and has implemented sophisticated waste sorting and recycling (PortWasteManagement.org, 2025)
- Integrate biodiversity and pollution mitigation into the heart of the ports' operations (India Maritime Week, 2025).

Capacity Building & Collaboration

- Promote knowledge sharing between global port authorities and technology partners to remove barriers in technology adoption (MDPI, 2025).
- Increase stakeholder engagement with carriers, logistics companies, local governments, and communities to align sustainability goals.

Indian ports can speed up their sustainable transformation by emulating the examples of global port leaders like Rotterdam, Singapore, and Los Angeles. Some of the critical areas in which these global port leaders can emulate include investing in smart digital technology, investing in renewable energy and shore power, embracing a circular economy and zero waste, and investing in environmental monitoring systems. Furthermore, a supportive policy framework, green incentives, and capacity-building programs are critical in speeding up adoption. By embracing technology, policy, and stakeholder engagement, Indian ports can successfully link their sustainability vision with the national initiatives of Sagarmala and the net-zero target.

Conclusion

The purpose of this study was to investigate the integration of sustainable principles in contemporary port operations with regards to adopting renewable energy sources, adopting automated systems, digitalization, and green management practices. The findings show that sustainable port development is no longer just an issue of complying with environmental regulations but rather a strategic imperative to drive operational efficiencies and competitiveness in ports. The integration of renewable energy sources with automated systems helps to reduce carbon emissions while increasing energy efficiency and cost-effectiveness.

The findings show that sustainable practices in ports, such as shore power, electrification of cargo handling equipment, environmental monitoring systems, waste management strategies, and smart port technologies, are important contributors to environmental sustainability while driving operational efficiencies in ports. Sustainability practices not only contribute to environmental sustainability but also enhance global competitiveness in ports by aligning with global climate regimes and evolving maritime conventions.

However, the study also identifies key challenges, particularly in developing economies, including high capital investment requirements, technological complexity, regulatory gaps, and stakeholder coordination issues. The limited focus on developing countries such as India in existing literature reveals a significant research gap. Overall, the study concludes that sustainable port development—driven by renewable energy, automation, and strategic policy support—is essential for achieving long-term operational excellence and progressing toward net-zero port targets between 2030 and 2050.

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Automation of Container Terminals and Impact on Global Trade

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Abstract

The aim and objectives of this research are to examine the effects of container terminal automation on global trade in terms of efficiency, competitiveness, and supply chain resilience. It is acknowledged that automation technologies such as automated guided vehicles, automated stacking cranes, and digital terminal operating systems have become increasingly prevalent in container terminals across the globe. However, existing studies on automation in container terminals have been fragmented and limited to advanced international container terminals. Less consideration has been given to a comprehensive assessment that considers the operational, economic, and socio-economic dimensions. Special consideration should also be given to emerging economies.

The research design employed in this paper is descriptive and analytical in nature. Secondary data was collected from peer-reviewed journals, global cases, and reports. A comparative analysis was done on automated and traditional container terminals based on key performance indicators such as ship turnaround time, container handling efficiency, berth productivity, and resilience to disruptions such as the COVID-19 pandemic.

The research findings show that automation in container terminals has a significant impact on efficiency, reliability, and resilience in global supply chains. However, challenges such as high investment costs, labor redundancy, and payback periods were also identified.

Keywords: Container terminal automation, Global trade, Port efficiency, Digitalization, Supply chain resilience

Introduction

Global trade heavily depends on container shipping, and container ports are a crucial link in global supply chains. With the constant increase in containers and vessel size, there has been a challenge in conventional terminal operations. To address the problem, there has been a shift towards automation technology, including AGVs, ASCs, and remote-controlled quay cranes, in container terminals globally (Iris, Pacino, & Ropke, 2022).

The use of automation technology has been seen as a means of enhancing port performance, as it increases terminal performance, reduces ship turnaround times, and increases the predictability of global trade chains (Kim, Kim, & Kang, 2022). For example, in the case of the COVID-19 pandemic, it has been seen that fully automated terminals have been more resilient compared to conventional terminals, as more vessel traffic has been managed, and there has been minimal berth waiting time (Kim, Kim, & Kang, 2022). This shows the potential of automation technology in enhancing the reliability of global trade chains.

However, despite these benefits, fewer than 5% of global container terminals are automated due to high capital investment needs, long payback periods, and socio-economic factors like resistance to change (Knatz, Notteboom, & Pallis, 2022). Moreover, studies show that while automation improves efficiencies in container terminals, its benefits depend on terminal sizes and regional trade flows, suggesting that context is an important factor in determining the impact of terminal automation (Li et al., 2024). Additionally, with the digitalization of ports, terminal automation is increasingly part of smart port initiatives that

leverage AI, IoT, and blockchain technologies to optimize supply chain visibility and competitiveness (Rodrigue, Notteboom, & Pallis, 2019).

With these considerations in mind, this thesis aims to investigate the impact of container terminal automation on global trade in terms of operational efficiencies, supply chain resilience, and strategic competitiveness in global trade.

Literature Review

Concept of Automation in Container Terminals

Container terminals are of critical importance for international trade as they provide the interface between maritime transport services and inland logistics services. With the growth of international trade in containers, larger vessel sizes, and increased demands for higher reliability and speed of transport services, there has been a growing problem of congestion, labor limitations, and operational inefficiencies in the operation of container terminals. Automation of container terminals has been considered a strategic solution to address these problems, including the use of technologies such as AGVs, ASCs, remote control of quay cranes, and terminal operating systems (PEMA, 2016; Dávid, 2019).

The initial research work considered the concept of automation as a technology-driven change that focused mainly on replacing human intervention with technology. Later research work extended this understanding of automation to cover changes to the overall system, including equipment, information flows, decision-making processes, and organizational structures (Steenken et al., 2004; Stahlbock & Voß, 2014). Park et al. (2021) emphasized that container terminal automation should be recognized as a socio-technical system in which OT interacts with human factors and external actors. This perspective has become increasingly important in the evolution towards smarter and more interconnected infrastructures.

Empirical studies show that the adoption rate of automation in different regions and container terminals varies considerably. Greenfield terminals such as APM Terminals Maasvlakte II were planned and developed with the aim of being fully automated, which facilitated the integration of AGVs, ASCs, and digital technologies (APM Terminals, 2015). By contrast, brownfield terminals tend to implement partial automation strategies because of space limitations and labor-related factors (Port of Los Angeles & TraPac, 2015; Li et al., 2024).

Automation and Operational Efficiency

One of the most common reasons for the automation of container terminals is operational efficiency. Several research studies have shown that there is a definite improvement in performance indicators such as ship turnaround time, berth productivity, yard utilization, and container dwell time through the automation of ports (Iris et al., 2022; Kim et al., 2022). Automated ports benefit from standardized operations, minimal human error, and better control of yard-crane operations.

Simulation-based research and optimization-focused research have been at the core of most research studies that have focused on quantifying the benefits of operational efficiency. Early research work carried out by Caserta et al. (2012) and Jin et al. (2015) focused on the block relocation problem. Later research work focused on the extension of these research studies to the case of automated ports, demonstrating that there is a definite benefit to operational efficiency in yards with high density (Tierney et al., 2017; Bacci et al., 2020). More recent research work using artificial intelligence techniques such as Monte Carlo Tree Search has shown that there is a definite benefit to operational efficiency (Zhang et al., 2025).

With regards to system-level monitoring and resource allocation, it can be said that further enhanced system-level results are possible. Yang et al. (2023) presented an instance

where monitoring with optimization was utilized to enhance crane-truck coordination at Yangshan Automated Container Terminal. The aforementioned is in line with surveys that highlighted the necessity for integration rather than isolated automations (Steenken et al., 2004; Park et al., 2021).

Impact of Automation on Global Trade Performance

The relationship between terminal automation and global trade performance is an issue that has gained more attention in recent times in an effort to understand its role in supply chain resilience. In this regard, automated terminals have proven to be more stable in times of crisis, including those involving labor shortages and those caused by the COVID-19 pandemic (Kim et al., 2022). In times of crisis caused by the COVID-19 pandemic, fully automated terminals experienced higher growth in throughput and reduced berth waiting times compared to conventional terminals.

In terms of its impact on global trade at the macro-level, it was established that congestion in ports directly influences volatility in freight rates (Frontiers in Marine Science, 2025; He & Lee, 2025). In this case, it can be understood that automation can play an important role in promoting stability in global trade. In this regard, UNCTAD (2021) emphasized that terminals with the capacity to sustain operations in times of crisis are able to create a competitive advantage in attracting shipping lines and cargo owners.

From a strategic perspective, it is also worth noting that automation changes the pattern of inter-port rivalry. According to Notteboom & Pallis (2020), technology's capability is considered to affect the port hierarchy. Ports that are well-equipped with technology are likely to connect better to hinterland corridors, digital platforms, and global alliances of shipping companies, thereby improving their position in international trade (Rodrigue et al., 2019; Li et al., 2024).

Financial Implications and Investment Trade-offs

Although there are operational advantages to the use of automation technology, there are also large financial commitments that need to be met. High capital costs, long payback times, and unknown growth in demand are still significant hurdles to overcome (Knatz et al., 2022). Cost savings between the use of automated terminals versus conventional terminals have been shown to be related to labor intensity, energy optimization, and asset utilization (OECD/ITF, 2021; PortEconomics, 2024).

The financial aspects of the use of automation technology have been shown to have different paths for greenfield versus brownfield projects. For greenfield projects, there is quicker operational optimization; however, there is a large investment to begin with. For brownfield projects, there is a phased approach to implementation with higher integration risks (APM Terminals, 2015; Port of Los Angeles & TraPac, 2015). The policy dataset from the OECD (2021) has shown that there are many aspects of financial feasibility that need to be considered.

Advanced optimization models can also contribute to cost efficiency by minimizing unproductive movements, equipment wear, and energy consumption (Cordeau et al., 2015; Djurasevic et al., 2024). These findings show that the financial benefits to be derived from automation depend not only on technology but also on discipline and optimization.

Digital Transformation and Smart Port Integration

Automation is becoming an integral component of a broader set of digitalization strategies to develop smart ports. Digital twins, IoT, AI, blockchain, and 5G connectivity enable better visibility, coordination, and decision support in terminal operations (Iris et al., 2022; IMDA/PSA, 2022). Rodrigue et al. (2019) highlighted the importance of integrating automation with digitalization to create substantial strategic value, while the ecosystem

enables the operation of smart ports as a platform to deliver data-driven logistics.

Empirical research on measuring the level of digitalization in ports by applying DEA to establish the level of digitalization highlights the heterogeneity in terms of digital efficiency, thus underpinning the significance of complementary managerial practices (Xu & Li, 2021). Open data strategies increase the scope for innovation in smart ports, which, in turn, creates challenges in terms of cybersecurity, etc. (Chen et al., 2022).

National policy frameworks increasingly acknowledge the importance of digitalization in driving automation in ports. UNCTAD (2021) and OECD/ITF (2021) emphasize the importance of standardized data protocols to enable the scale-up of automation in the global network of ports.

Social and Labor Implications of Automation

Although automation is known to boost productivity, the social implications of automation have remained a key area of concern. Several research papers have highlighted the social impacts, including workforce replacement, job restructuring, and skill divergence in automated terminals (Xu & Luo, 2023; Milkman & Torres, 2023). In this context, Lin and Wu (2016) discussed automation in terms of responsible innovation, which focuses on the balance between efficiency and social acceptability.

Several empirical research papers have highlighted the fact that automation is not likely to result in job loss, but it is likely to change the nature of jobs, with a higher demand for technical, supervisory, and data-related skills (van der Lugt, 2022). However, lack of proper transition measures may result in workforce resistance and social conflicts, particularly in brownfield terminals with high unionization (Knatz et al., 2022; TRB, 2021).

Research papers have suggested the need to develop participatory transition measures to minimize the negative impacts on the workforce (OECD/ITF, 2021; Xu & Luo, 2023), which clearly highlights the fact that successful automation is linked to institutional preparedness, in addition to technological preparedness.

Research Gaps and Synthesis

However, there exist some gaps in the literature. Firstly, the literature mainly discusses individual subsystems rather than terminal performance. This creates limitations in the discussion on system-wide effects on global trade. Secondly, there is limited comparative empirical research on the direct relationship between automation and global trade. Thirdly, social and governance factors have been considered secondary factors rather than integral components in automation strategies. This study aims to bridge these gaps by considering the different dimensions in evaluating the impact of container terminal automation on global trade. By considering the different dimensions in evaluating the impact of automation on global trade, the literature creates a comprehensive foundation on which to analyze the different effects of automation on global trade.

Objectives

1. To study how automation in container terminals makes work faster and smoother for global trade.
2. To understand how automation changes costs, profits, and competition in international trade.
3. To study the problems and challenges automation brings, like job losses or high expenses.

Research Methodology

Research Design

The research design that is adopted in this study is descriptive and analytical in nature. The reason for its descriptive nature is that it seeks to describe existing practices in automated terminals in container shipping. It is also analytical in nature because it seeks to analyze and synthesize findings from different studies to determine its impact on global trade.

Sources of Data

The sources of data that are used in this study are based on secondary data only. In other words, no primary data collection is done in this study.

Academic Literature: Journal publications in Scopus, Web of Science, ScienceDirect, Springer, and MDPI.

Case Studies: Examples of automated terminals in different parts of the world, such as Maasvlakte II in Rotterdam, Yangshan in China, and TraPac in Los Angeles.

Industry Reports: Reports published by OECD/ITF, UNCTAD, World Bank Group, IMO, and maritime organizations in different countries.

Books and Edited Volumes: Port Economics, Automation in Container Terminals, and Maritime Logistics.

Target Population

The target population in this study includes published academic literature, case studies, industry reports, and policy reports related to automation in container terminals and its impact on global trade.

Element: Research papers, case studies, and industry reports on container terminal automation and global trade.

Sampling Unit: An individual research paper, case study, or industry report on container terminal automation and global trade, which is identified from the above databases.

Geographical Scope: Global, with reference to advanced countries (Europe, Asia, America) and Indian ports (JNPT, Vizhinjam).

Time Frame: August 2025-26.

Sampling Frame

Academic databases: Scopus, Web of Science, ScienceDirect, Springer, MDPI, ResearchGate.

Repositories: OECD/ITF, UNCTAD, World Bank, IMO, national maritime authorities.

Reports from port authorities and global case studies on automated container terminals.

Sampling Technique

Purposive Sampling: Only the most relevant research papers, case studies, and industry reports on container terminal automation and global trade are included.

Sample Size

Approximately 40 to 60 research papers, case studies, and industry reports on container terminal automation and global trade, which are identified from the above databases, are included in this study.

Discussion

Automation Influence Operational Efficiency Indicators

- **Impact of Automation on Ship Turnaround Time**

The impact of automation in container terminals is quite significant in improving ship turnaround time, which is considered a critical indicator of port efficiency and global trade facilitation. Ship turnaround time is considered to be the time gap between the ship's arrival at the berth and its subsequent departure from the berth after completing cargo handling operations. Literature that compares the performance of automated and conventional container terminals indicates that automation helps to achieve better synchronization between ship-to-shore cranes, yard cranes, and transport vehicles. For example, Jobran & Kara (2022) indicated that through their simulation analysis of automated container terminals, they were able to achieve a reduction in ship turnaround time from 9.52 hours to 7.81 hours, indicating a reduction of approximately 18%. This is mainly due to the benefits of using automated scheduling systems to achieve continuous equipment availability without human intervention.

- **Impact of Automation on Container Dwell Time**

Container dwell time, which is the period a container spends inside the terminal before being moved out, is another important indicator affected by automation. Automated stacking cranes (ASC), automated guided vehicles (AGV), and terminal operating systems (TOS) minimize congestion in container terminals due to efficient container positioning and movement. According to Portwise Consultancy (2023), smart technology in ports helps in monitoring and predicting the allocation of containers in real-time. This helps in minimizing unnecessary reshuffling and reduces dwell times. Although customs clearance and inland transport are also important factors in dwell times, automated systems contribute to improving the operational part of dwell times by optimizing terminal operations and truck turnaround times. Therefore, reduced dwell times contribute to improving the smoothness of cargo flows and minimizing trade costs for global trade participants.

- **Impact of Automation on Berth Productivity**

Berth productivity, as defined, is the number of container moves per berth or per crane over a specific time frame. Automation increases berth productivity since it allows terminals to operate continuously, i.e., 24/7, with consistent performance levels. Automated quay cranes, along with a digitalized yard, eliminate downtime between container moves, thus increasing efficiency. Jobran & Kara (2022) found that automated terminals have a higher crane usage compared to traditional terminals, as the operating cycles of automated terminals are standardized, thus reducing the need for human intervention. Increased berth productivity means that ships will be handled more efficiently, reducing congestion at ports, thus improving schedule reliability for shipping lines, which will have a positive impact on global trade efficiency.

Comparative Evidence Exists Between Automated and Conventional Container Terminals Regarding Trade Facilitation

Comparative studies show conclusive proof that automated container terminals perform better than traditional container terminals, especially when faced with stressful situations. This was demonstrated in a research paper on the performance of fully automated and non-

automated container terminals in the pre- and post-COVID-19 pandemic periods. The paper was published in Sustainability. The results indicated that the performance of fully automated container terminals improved by 30.18% in 2020 compared to 2019. Contrary to this improvement in automated container terminals, non-automated container terminals declined by 1.91% in 2020 compared to 2019 (Sustainability, 2023).

In addition to this improvement in performance, the same paper indicated that the average time spent by ships in berths increased by only 4.59% in automated container terminals. This was in contrast to non-automated container terminals, which increased by 16.23% in 2020 compared to 2019 (Sustainability, 2023). The number of ships that arrived at automated container terminals also increased by 21.8%, while non-automated container terminals declined by approximately 3.05%. This information shows conclusively that automated container terminals perform better than non-automated container terminals.

Automation Improved Resilience in Global Trade During Disruptions

The role of automation in the development of resilience in global trade in the face of disruptions such as the COVID-19 pandemic and port congestion cannot be overstated. Some of the benefits of the resilience of global trade to disruptions through the application of automation technology include reduced reliance on human labor. For instance, during the COVID-19 pandemic, there were labor shortages and restrictions that impacted the conventional operation of ports across the globe. However, fully automated ports were still operational with minimal human intervention to facilitate the movement of cargo and the service of vessels (Sustainability, 2023).

Furthermore, there is the benefit of increased predictability of operations through the application of digital technology. For instance, there is the possibility of responding to sudden changes in vessel calls through the application of digital technology. According to Portwise Consultancy (2023), there is the possibility of responding to shocks such as congestion through the application of digital technology to the operations of ports.

Impact of Automation on terminal operating costs and overall profitability

Impact on Operating Costs

- Automated terminals help in reducing labor costs, which constitute a major share of overall operating costs. It has been estimated that automation can bring down the overall operating costs by 15-55%, depending on the design and efficiency of integration. Estimates by the industry suggest that automation can bring down operating costs by 25-55%.
- Fully automated terminals have been seen to bring down costs by 37% and associated carbon emissions by 50%, with a corresponding improvement in productivity by ~40% compared to non-automated operations.
- However, automation also leads to an increase in capital costs because automated equipment and infrastructure tend to be very expensive.

Impact on Profitability

- Profitability is greatly influenced by the stable operation of fully automated terminals. The study showed an increase in total terminal profit in fully automated terminals by \$501 million (25.9%) from 2019 to 2020, while non-automated terminals had a decline in total terminal profit by \$133 million (2.3%).
- The increase in total terminal throughput, which is a key revenue driver, contributed to the increase in profitability, where fully automated terminals had an increase in total terminal throughput by ~30.18%.

Impact of Automated terminals on global ports' competition: service reliability and throughput

Throughput and Operational Performance

- A higher operational throughput has been recorded during disruptions for automated terminals; for fully automated terminals, there is a ~30.18% increase in throughput, whereas for non-automated terminals, there is a decline of -1.91% during the same period (2019-2020).
- A more stable operational performance is provided through automated systems; for instance, there is only a ~4.59% increase in ship berthing times for automated terminals, whereas for non-automated terminals, there is a ~16.23% increase.

Service Reliability

- A more reliable service is provided through the use of automated systems; for instance, there are minimal interruptions due to labor variability.
- A higher number of ULCS can be accommodated at ports that have the capability for automation; 24/7 services can be provided.

Competitive Positioning

- Since throughput and reliability have a direct bearing on shipping line preferences, ports that have adopted automation are at a competitive advantage in the international arena. This is because automation helps ports to serve a large number of ship calls, decrease vessel waiting times, and increase volume – all of these being critical determinants of competitiveness in international trade. Because throughput and reliability directly affect shipping line preferences, ports with automation are positioned more competitively in global networks. Automation enables terminals to handle high ship calls, reduce vessel waiting times, and scale volumes—critical competitive factors in international trade.

Financial trade-offs (capital investment vs. long-term returns) are highlighted in case studies of automated container terminals

Capital Investment (CAPEX)

- High capital costs are involved in automation projects. The capital costs of equipment like AGV, ASC, advanced TOS, etc., can run into hundreds of millions of dollars, especially in full automation.
- A survey of the industry has revealed that 62% of terminal professionals rate high initial investment as the main barrier in the implementation of automation.

Operational Savings and ROI

Though high capital costs are involved in automation, it can result in operational savings in the long term. The ROI on an automation project can be expected in 5-7 years, depending on the throughput and labor cost environment.

- Another study has revealed that a viable ROI can be expected when the labor costs exceed 40% of total costs, and throughput is more than 1-1.5 million TEU/year.

Trade-Offs

- Terminal automation has a trade-off between high investment costs and future cost savings, as well as increased revenues through increased throughput. Although terminal automation significantly reduces operating costs, the return period and profitability depend on the integration, throughput, and cost of labor, as well as execution strategies.

The major socio-economic challenges associated with terminal automation (e.g., job displacement, skill gaps, and labor resistance).

Terminal automation also presents a range of socio-economic challenges, which include job displacement, skills mismatch, and resistance from the workforce. The use of terminal automation in containers reduces the need for human resources in the form of crane drivers, yard drivers, and dockworkers. This has led to a reduction in the workforce in several terminals globally (International Transport Forum [ITF], 2021).

Although automation has led to the creation of new jobs, it has also led to a skills mismatch, as the new jobs require expertise in managing technology, which most existing workers lack (McKinsey & Company, 2018).

Such a transition is more likely to impact low-skilled workers in a disproportionate manner, thus causing income inequality and polarization in the labor market (Acemoglu & Restrepo, 2020). Moreover, in most ports where strong labor unions are present, automation projects are resisted due to apprehensions regarding job security and wages, which ultimately leads to industrial conflicts against port authorities (Notteboom & Pallis, 2021).

At the community level, apart from individual workers, socio-economic insecurity in ports can arise due to a decline in employment opportunities caused by large-scale automation projects (UNCTAD, 2022).

High capital investment and long payback periods affect the adoption of automation.

The adoption of terminal automation largely depends on the capital costs that are incurred. Fully or semi-automated terminal operations are associated with considerable capital costs related to automated stacking cranes, automated guided vehicles, terminal operating systems, and digital integration platforms. These are largely irreversible capital investments that are associated with considerable financial risks, considering factors like cargo volume risks and the volatility of international trade. These risks are further exacerbated by the fact that the adoption of automated terminal operations does not necessarily result in immediate productivity improvements. Rather, it may take several years to attain operational optimization, causing a considerable delay in the expected financial returns. This may largely deter small and medium-sized terminal operators from considering terminal automation.

This situation may be largely mitigated by global terminal operators that have considerable capital base capabilities to withstand the considerable payback period of terminal automation. This situation may cause considerable heterogeneity in the adoption of terminal automation.

Challenges in the adoption of automation.

For addressing socio-economic and financial issues, several workforce-related strategies, institutional strategies, and financial strategies are recommended in existing literature and policy reports. The most important strategy recommended in existing reports is to invest heavily in workforce-related strategies to reskill and upskill displaced workers in technical positions related to maintaining automated equipment, information technology systems, and digital logistics management (McKinsey & Company, 2018).

Social dialogue and stakeholder engagement are also recommended to minimize resistance to change and develop negotiated transition frameworks among port authorities, terminal operators, trade unions, and governments (ITF, 2021). Introducing wage insurance and retraining subsidies can also play an important role in providing social protection to workers and smoothening the adjustment process in the labor market (UNCTAD, 2022)).

From a financial point of view, a phased approach to automation, rather than a fully

automated one, would enable container terminals to spread their financial costs over time and minimize disruptions to their operations (Notteboom & Pallis, 2021). Public-private partnerships, innovation funding, and financial incentives have also been advocated to help make the investment case more attractive and ensure that automation aligns with economic and social objectives. All these measures would help in the achievement of a “just transition” to automation.

Conclusion

This study aimed at the impact of container terminal automation on global trade by taking into consideration operational, economic, and socio-economic factors. The study results clearly indicate the positive impact of automation on the operational efficiency of container terminals. The key operational efficiency indicators, which include ship turnaround time, berth productivity, container dwell time, and container throughput, have shown improvements in automated container terminals compared to traditional container terminals. The study has used real-world examples from some of the most advanced automated container terminals, such as **APM Terminals Maasvlakte II, Yangshan Automated Container Terminal, and TraPac Terminal**, which have shown improvements in terms of operational coordination, reduced operational delays, and schedule reliability. During the COVID-19 pandemic, which caused operational disruptions in the global trade, the automated container terminals showed higher resilience in terms of maintaining higher growth in container throughput and reduced waiting times at the berths.

In financial terms, automation creates a strategic trade-off in terms of high initial investment against future operating benefits. Although automated terminals involve high investment in advanced equipment and technologies, they also help to minimize costs by reducing labor intensity, optimizing energy efficiency, and maximizing asset utilization. Profitability benefits in automated ports correlate well with increases in throughput and service reliability, which in turn help to position these ports more favorably in the global maritime economy. However, the investment payoff also depends on the size of the terminal, labor cost structure, and cargo volumes.

Despite these advantages, there are also many socio-economic problems that may arise from the adoption of automation technology. For instance, there is the problem of job loss, skills mismatch, labor unrest, and access to capital that may hinder the adoption of technology in emerging markets. There is a need to develop supportive policy frameworks for the adoption of technology to promote the transition to automation.

In conclusion, the adoption of container terminal technology is not just a simple technology upgrade; it is a transformation that will define the future of global trade. The adoption of technology is beneficial to the development of stronger ports, stronger supply chains, and increased international competitiveness. However, for technology to be beneficial to the development of global trade in the future, there is a need to address the issue of balancing technology innovation with financial sustainability and social responsibility.

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Global Trade through Smart Ports and Integrated Port Management

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Abstract

The rapid growth of global trade has pushed seaports to evolve from traditional cargo handling points into smart, technology-driven logistics hubs. This study explores how automation, digitization, and digitalisation are transforming port performance and improving global supply chain efficiency, with a special focus on Indian ports. It examines the influence of technologies such as automated cranes, smart warehousing, the Internet of Things (IoT), and data-driven management systems on key operational indicators like vessel turnaround time, cargo throughput, and multimodal connectivity. Using a comparative and analytical approach supported by an extensive literature review and secondary data, the research also evaluates how smart port systems enhance supply chain resilience through real-time and adaptive operations. The findings suggest that the adoption of advanced digital technologies significantly improves efficiency, reduces congestion, and strengthens coordination between sea, rail, and road transport. However, challenges such as high implementation costs, integration complexity, and workforce readiness continue to affect large-scale adoption. By focusing on the Indian maritime context, this study offers practical insights for policymakers, port authorities, and logistics stakeholders aiming to improve trade competitiveness through smart and integrated port management.

Keywords: Smart Ports, Port Automation, Digitalization, Multimodal Transport, Supply Chain Resilience, Maritime Logistics, Indian Ports

Introduction

The expansion of global trade has increased the complexity of modern supply chains, putting pressure on seaports to evolve beyond their traditional role as cargo transfer points. Today, ports are not just physical infrastructure but digital ecosystems—central to the performance, resilience, and sustainability of international logistics. Smart ports, enabled by automation, digitisation, and data-driven decision-making, have become vital for improving trade efficiency, reducing turnaround times, and enabling seamless multimodal integration across rail, road, and water transport.

The traditional port management model—often reliant on manual processes, paper documentation, and disconnected operations—can no longer meet the demands of fast-moving global commerce. Modern smart ports leverage advanced technologies such as automated cranes, smart warehousing, AI-powered analytics, blockchain-based Port Community Systems (PCS), and Internet of Things (IoT) devices. These technologies significantly reduce vessel turnaround time, increase cargo throughput, and facilitate real-time cargo tracking and resource optimisation (Heilig, Lalla-Ruiz, & Voß, 2017). As a result, ports transform from passive transit zones into active nodes in supply chain coordination, capable of synchronizing inland logistics via rail, road, and inland waterways.

In the Indian context, ports play a particularly crucial role. More than 95% of the country's trade by volume and 70% by value pass through its maritime gateways (Ministry of Ports, Shipping and Waterways, 2021). As India aims to become a global manufacturing and export hub under initiatives like 'Make in India' and 'PM Gati Shakti,' enhancing port efficiency and multimodal logistics integration is essential. The Indian government's **Maritime India Vision 2030** outlines a strategic framework for transforming major ports into smart,

digitalized, and green logistics hubs. Within this vision, automation and digitalization are seen as tools to not only improve operational efficiency but also reduce logistics costs and improve international trade competitiveness.

Smart port technologies are not merely operational enhancements; they represent a structural transformation in how ports function within global supply chains. Through automation, data integration, and multimodal connectivity, ports can become agile, resilient, and intelligent systems that support sustainable global trade. This study will investigate these dimensions by focusing on the Indian port landscape, using real-world applications to assess how smart infrastructure and digital systems improve trade facilitation and intermodal logistics efficiency.

Literature Review

A Review on Reinforcement Learning Algorithms and Applications in Supply Chain Management

This study reviews how reinforcement learning (RL) techniques can be used in supply chain management to deal with complex and uncertain environments. It discusses algorithms such as Q-learning and policy gradient methods for tasks like inventory management, demand forecasting, and logistics planning. The paper highlights how advancements in data availability, computing power, and artificial intelligence are improving supply chain decision-making. However, the study notes that the real-world adoption of RL in logistics is still limited due to computational challenges, lack of sufficient data, and the complexity of supply chain networks. The authors suggest conducting more practical studies to bridge the gap between theoretical models and real-world applications.

Rolf, B., Jackson, I., Müller, M., Lang, S., Reggelin, T., & Ivanov, D. (2023). A review on reinforcement learning algorithms and applications in supply chain management. International Journal of Production Research, 61(20), 7151–7179.

An Integrated Event-Driven Real-Time Tactical–Operational Optimization Framework for Smart Port Operations Planning

This research introduces an event-driven framework designed to improve decision-making in smart port operations. The framework integrates tactical and operational planning, allowing ports to respond quickly to disruptions such as congestion or supply chain delays. By using decision support systems and real-time data, the model helps optimize workflows and improve operational efficiency. The study tested the framework using real port data and found significant improvements in cargo handling and operational planning. It demonstrates how digital technologies can help ports manage uncertainties and reduce delays.

Abril, D., Paternina-Arboleda, C. D., & Velasquez-Bermudez, J. (2024). An integrated event-driven real-time tactical–operational optimization framework for smart port operations planning. Logistics, 8(3), 65.

Analysis of Modern Port Technologies

This study analyzes the role of modern technologies in improving port operations and logistics efficiency. It focuses on automation systems, information technologies, and digital platforms that help improve cargo handling and operational coordination. The research highlights the importance of updated IT systems for smooth communication between different stakeholders in the port ecosystem. It also discusses how technological innovation helped ports maintain operations during disruptions such as the COVID-19 pandemic. The study concludes that adopting digital solutions is essential for ports to remain competitive and efficient in global trade.

Kosiek, J., Kaizer, A., Salomon, A., & Sacharko, A. (2025). *Analysis of modern port technologies based on literature review. Multimodal Transportation, 4, 100211*

Autonomous Fleet Management System in Smart Ports: Practical Design and Analytical Considerations

This paper examines the use of autonomous fleet management systems (AFMS) in container terminals. Unlike traditional systems where vehicles operate independently, AFMS uses centralized control to coordinate multiple vehicles and improve communication between them. The study explains how such systems enhance horizontal transportation efficiency and reduce operational risks in container terminals. It also identifies key features such as fleet coordination, cluster intelligence, and system integration. The research highlights that AFMS can significantly improve port logistics and support sustainable port operations.

Chen, R., Zhang, J., & Wang, H. (2025). *Autonomous fleet management system in smart ports: Practical design and analytical considerations. Multimodal Transportation, 4, 100211.*

A way towards port automation: challenges and implications

This study explores the growing trend of automation in ports and its potential benefits. Technologies such as Automated Guided Vehicles (AGVs) and Automated Stacking Cranes (ASCs) are being used to improve efficiency and reduce operational costs. Research shows that automation can increase productivity and reduce costs significantly. However, the transition to automation also brings challenges such as high investment costs, labor issues, lack of skilled workers, and operational inefficiencies during the transition phase. The study emphasizes the need for better planning and workforce training to ensure successful implementation.

De Alwis, N., & Nam, H.-S. (2025). *A way towards port automation: Challenges and implications. WMU Journal of Maritime Affairs, 24(2), 225–247.*

Automation in port container terminals

This research focuses on the adoption of automated technologies in container port terminals. Technologies such as AGVs, automated cranes, and remote-controlled equipment are replacing manual operations to improve productivity and safety. Although only a small percentage of ports globally are fully automated, large terminals and transshipment hubs are increasingly adopting these technologies. The study shows that automation can significantly increase throughput and reduce operational costs. However, it also highlights challenges such as high investment requirements, integration issues, and resistance from workers.

Rodrigue, J.-P., & Notteboom, T. (2021). *Automation in container port systems and management. TR News, 334, 20–27.*

Automation Processes in the Port Industry and Union Strategies: The Case of Antwerp

This study examines how automation in ports affects labor relations and employment structures. While automation promises increased efficiency and reduced labor costs, its actual impact on productivity has sometimes been limited. The research highlights how automation often changes job roles rather than eliminating them completely. The case of Antwerp shows how strong labor unions negotiated training programs and job protections during automation transitions. The study highlights the balance required between technological progress and workforce stability.

Bottalico, A. (2022). *Automation processes in the port industry and union strategies: The case of Antwerp. New Global Studies, 16(1), 31–47.*

Challenges in the Digital Transformation of Ports

This paper discusses the opportunities and challenges associated with digital transformation in ports. Technologies such as IoT, artificial intelligence, blockchain, and big data are improving efficiency and transparency in port operations. These technologies help optimize logistics and improve decision-making. However, the study also identifies challenges such as cybersecurity risks, lack of standardization, and difficulties in integrating systems among different stakeholders. The authors emphasize that successful digital transformation requires not only technological adoption but also institutional readiness and skilled human resources.

Ruiz-Aguilar, J. J., Núñez-Ríos, J. E., & González-Cancelas, N. (2022). Challenges in the digital transformation of ports. Journal of Marine Science and Engineering, 10(5), 596.

Cloud Computing For Supply Chain Management

This study explains how cloud computing is transforming supply chain management by providing scalable and cost-effective digital infrastructure. Cloud platforms allow organizations to share data in real time, which improves coordination among supply chain partners. The research highlights services such as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS), which support logistics planning, inventory management, and procurement activities. While cloud computing offers many benefits, challenges related to data security, system integration, and reliability still exist.

Bhoir, H., & Patil, R. (2014). Cloud computing for supply chain management. International Journal of Innovations in Engineering Research and Technology, 1(2), 1–9.

Cloud computing in logistic and supply chain management environments

This study examines the role of cloud computing in the digital transformation of logistics and supply chain management. It explains how cloud technologies reduce infrastructure costs, increase scalability, and improve collaboration among supply chain stakeholders. The integration of cloud systems with technologies like IoT, blockchain, and artificial intelligence further enhances operational efficiency. Despite these advantages, challenges such as data security risks and system compatibility remain. Overall, the research highlights cloud computing as a key enabler for innovation and competitiveness in logistics networks.

Temjanovski, R., Bezovski, Z., & Apasieva, T. J. (2021). Cloud computing in logistic and supply chain management environments. UTMS Journal of Economics, 12(2), 215–233.

Cloud computing in supply chain management: Exploring the relationship

This paper analyzes how cloud computing supports supply chain management by enabling real-time data sharing and collaboration. The authors explain that cloud-based platforms improve supply chain visibility and decision-making through data analytics and automation tools. The study also discusses potential risks such as data privacy concerns, vendor dependency, and system failures. A case study included in the research demonstrates how companies can successfully implement cloud-based supply chain systems. The study concludes that cloud technology can significantly improve supply chain efficiency if managed properly.

Yenugula, M., Sahoo, S. K., & Goswami, S. S. (2023). Cloud computing in supply chain management: Exploring the relationship.

Constructing Governance Framework of a Green and Smart Port

This study develops a governance framework for the development of green and smart ports. Using Interpretative Structural Modeling (ISM), the authors identify 20 key factors that influence smart port development. The study highlights six important characteristics:

greenness, agility, personalization, cooperation, intelligence, and openness. These factors help governments and port authorities design policies that support sustainable port development. The research provides a structured approach for integrating environmental sustainability with digital transformation in port operations.

Chen, J., Huang, T., Xie, X., Lee, P. T.-W., & Hua, C. (2019). *Constructing Governance Framework of a Green and Smart Port*.

Container terminal automation: revealing distinctive terminal characteristics and operating parameters.

This study analyzes the development of automation in container terminals across the world. The authors compiled data from 63 fully and semi-automated terminals to understand where and how automation is being implemented. The research shows that only a small percentage of global container terminals are currently automated. It also examines how terminal operators evaluate automation investments and the time required to recover costs. The findings help port authorities and operators better understand the operational and financial considerations involved in adopting terminal automation.

Knatz, G., Notteboom, T., & Pallis, A. A. (2022). *Container terminal automation: revealing distinctive terminal characteristics and operating parameters*. *Maritime Economics & Logistics*, 24, 537–565.

Container terminal operation and operations research—A classification and literature

This paper provides a comprehensive review of operational processes in container terminals and the role of operations research in improving efficiency. The authors classify major logistics activities such as berth allocation, yard management, and container handling. The study highlights how information technology and optimization models help manage the growing volume of container traffic. A key focus is on reducing ship berthing time, which is an important factor for port competitiveness. The research provides a strong theoretical foundation for improving port logistics and operational planning.

Steenken, D., Voß, S., & Stahlbock, R. (2004). *Container terminal operation and operations research a classification and literature review*. *OR Spectrum*, 26, 3-49.

Design and evaluation of a scalable Internet of Things backend for smart ports

This study presents a cloud-based IoT platform designed for smart port environments. The system was developed under the EU's PortForward project to manage large volumes of data generated by sensors and smart devices in ports. The platform integrates multiple IoT communication protocols and provides secure data access to different stakeholders. The research demonstrates its functionality using an air quality monitoring case in the Port of Antwerp. The results show that scalable IoT platforms can significantly improve data management and operational monitoring in smart ports.

Bracke, V., Sebrechts, M., Moons, B., Hoebeke, J., De Turck, F., & Volckaert, B. (2021). *Design and evaluation of a scalable Internet of Things backend for smart ports*. *Software: Practice and Experience*, 51(7), 1557–1579.

Developing a roadmap for implementing digital transformation to improve the resilience of port operations.

This study proposes a roadmap for implementing digital transformation in port operations to improve resilience and efficiency. The framework includes three main stages: evaluation and planning, implementation of new technologies, and continuous monitoring and improvement. The research emphasizes the importance of identifying operational goals, allocating resources, and training employees during digital transformation. It also highlights the role of stakeholder collaboration in successfully implementing new technologies. The

study concludes that gradual implementation and continuous evaluation are essential for effective digital transformation in ports.

Developing a smart port architecture and essential elements in the era of Industry 4.0

This research discusses how ports must adapt their operations to the Industry 4.0 environment. The author proposes a conceptual architecture for smart ports and identifies key elements required for their development. These include digital infrastructure, performance indicators, and integrated operational systems. The study highlights the importance of data-driven decision-making and technological innovation in modern port operations. It provides a framework that can guide ports in planning their digital transformation strategies.

Digital Twins for Ports: Derived From Smart City and Supply Chain Twinning Experience.

This paper explores the concept of digital twins and their potential application in port operations. A digital twin is a virtual model that replicates real-world systems using real-time data. The research identifies three essential components for a port digital twin: situational awareness, collaboration between stakeholders, and advanced data analytics. The study also suggests that digital twins can help ports optimize resource use, improve operational efficiency, and reduce energy consumption. It highlights the growing importance of digital technologies in port management.

Klar, R., Fredriksson, A., & Angelakis, V. (2023). Digital Twins for Ports: Derived From Smart City and Supply Chain Twinning Experience.

IEEE Access, 11, 71777–71799 .

Digitalizing the maritime supply chain: The case of Rotterdam's port call operations.

This study examines how digitalization improves maritime supply chain operations, using the Port of Rotterdam as a case study. The port introduced a digital platform called PortXchange, which allows stakeholders to share operational data in real time. This system helps reduce waiting times for vessels and improves coordination among port participants. The research also shows that digitalization can reduce carbon emissions by minimizing idle vessel time. However, challenges such as lack of data standardization and trust among stakeholders still remain.

Suvadarshini, P., & Dandapat, P. (2023). Digitalizing the maritime supply chain: The case of Rotterdam's port call operations. Journal of Information Technology Teaching Cases, 13(2), 170–174.

Energy–Logistics Cooperative Optimization for a Port-Integrated Energy System.

This study proposes an optimization model that integrates energy management with port logistics operations. The model considers factors such as ship operations, crane activities, and energy consumption within the port system. Using a case study of Shanghai Port, the research demonstrates that the proposed model can reduce operational costs while improving efficiency. The study highlights the importance of integrating logistics planning with sustainable energy systems to achieve environmental goals.

Mo, A., Zhang, Y., Xiong, Y., Ma, F., & Sun, L. (2024). Energy–Logistics Cooperative Optimization for a Port-Integrated Energy System, Mathematics, 12(1917).

Gate automation system evaluation.

This research evaluates gate automation systems used in port terminals to improve container identification and processing. The study focuses on container number recognition systems (CNRS) and compares different technological options. Using a case study from

Keelung Port, the authors apply analytical methods to determine the most effective system. The findings indicate that RFID technology provides the most reliable and efficient solution for gate automation. The research offers a useful framework for port managers when selecting automation technologies.

Chao, S.-L., & Lin, Y.-L. (2017). *Gate automation system evaluation: A case of a container number recognition system in port terminals*. *Maritime Business Review*, 2(1), 21–35.

Hindrances in port digitalization?

This study investigates the challenges that ports face when adopting digital technologies. Although digitalization improves efficiency and sustainability, many ports struggle during the initial implementation stages. The research identifies major barriers such as resistance to change, limited financial resources, lack of technical expertise, and incompatible digital systems among stakeholders. The study emphasizes that strong leadership and clear strategic planning are essential for successful digital transformation in ports.

Brunila, O.-P., Kunnaala-Hyrkki, V., & Inkinen, T. (2021). *Hindrances in port digitalization? Identifying problems in adoption and implementation*. *European Transport Research Review*, 13(62).

Intelligent Supply Chain Integration and Management Based on Cloud of Things.

This study introduces a Cloud of Things (CoT) framework to improve supply chain integration and management. The system combines cloud computing with IoT technologies to collect real-time operational data through devices such as RFID and barcode systems. These data are then converted into cloud-based services that help organizations manage logistics activities more efficiently. The research demonstrates that such systems can improve flexibility, coordination, and responsiveness in supply chains.

Yan, J., Xin, S., Liu, Q., Xu, W., Yang, L., Fan, L., Chen, B., & Wang, Q. (2014). *Intelligent Supply Chain Integration and Management Based on Cloud of Things*. *International Journal of Distributed Sensor Networks*, 2014, 1–15.

Internet of Things for Smart Ports: Technologies and Challenges.

This paper examines how IoT technologies can be used to develop smart ports. It discusses the use of sensors, cameras, and tracking systems to monitor container movements, vehicles, and port equipment. The study also explains how IoT enables real-time communication between different port systems. Although IoT improves operational efficiency and safety, the research highlights challenges such as system integration, data security, and infrastructure requirements.

Yang, Y., Zhong, M., Yao, H., Yu, F., Fu, X., & Postolache, O. (2018). *Internet of Things for Smart Ports: Technologies and Challenges*. *IEEE Instrumentation & Measurement Magazine*, 21(1), 34–43.

Management of Containers by the Use of Automatic Cranes- New Handling Method.

This study investigates time inefficiencies in container handling operations within port stacking yards. It compares traditional crane systems with an automated storage and retrieval system (AS/RS). Using simulations and statistical analysis, the research identifies operational steps that cause delays. The results suggest that automated handling systems can significantly reduce time wastage and improve container movement efficiency in port terminals.

Jasim, J. H. (2015). *Management of Containers by the use of Automatic Cranes- New Handling Method (Unpublished master's thesis)*. Chalmers University of Technology, Gothenburg, Sweden.

Operational efficiency and sustainability in smart ports.

This study reviews existing research on smart ports and their role in improving operational efficiency and environmental sustainability. The authors analyzed over 200 research papers using scientific mapping techniques. The results show that research on smart ports has increased significantly since 2019. Key themes include Industry 4.0 integration, maritime security, and green port development. The study concludes that smart technologies play a vital role in improving port sustainability and operational performance.

Alzate, P., Isaza, G. A., Toro, E. M., Jaramillo-Garzón, J. A., Hernandez, S., Jurado, I., & Hernandez, D. (2024). *Operational efficiency and sustainability in smart ports: a comprehensive review*. *Marine Systems & Ocean Technology*, 19, 120–131.

Perspectives for port development, based on automated container handling technologies.

This research compares automated and conventional container handling systems in port terminals. Using a case study approach, the authors evaluate operational performance, cost efficiency, and environmental impact. The study shows that automated systems can significantly reduce operational costs and carbon emissions while improving safety and productivity. The findings highlight the importance of automation for sustainable port development.

Gattuso, D., & Pellicanò, D. S. (2023). *Transportation Research Procedia*, 69, 360–367.

Port Digitalization with Open Data.

This study examines the role of open data in port digitalization. Open data refers to digital information that is freely accessible and machine-readable. The research shows that open data can support better decision-making and operational transparency in ports. However, challenges such as limited funding, lack of data management strategies, and technical compatibility issues slow down its adoption. The study concludes that improving data governance is essential for successful digitalization.

Inkinen, T., Helminen, R., & Saarikoski, J. (2019). *Journal of Open Innovation: Technology, Market, and Complexity*, 5(2), 30.

Ports: A Parallel, Optimistic, Real-Time Simulator

This research introduces a simulation system designed to model real-time port operations. The simulator allows port managers to analyze operational scenarios and predict system performance under different conditions. By using parallel computing methods, the system improves the speed and accuracy of simulations. Such tools can help ports optimize operational planning and decision-making.

Ghosh, K., Panesar, K., Fujimoto, R. M., & Schwan, K. (n.d.). *PORTS: A Parallel, Optimistic, Real-Time Simulator*.

Reducing external container trucks' turnaround time in ports: A data-driven approach under truck appointment systems.

This study proposes a data-driven approach to reduce the turnaround time of container trucks in ports. Using smart gate data, the authors analyze the relationship between truck arrivals and waiting times. The research develops an optimization model that schedules truck appointments more efficiently. The results show that the proposed system significantly reduces congestion and improves port logistics efficiency.

Sun, S., Zheng, Y., Dong, Y., Li, N., Jin, Z., & Yu, Q. (2022). *Computers & Industrial Engineering*, 174, 108787.

Scheduling of container-handling equipment during the loading process at an automated container terminal.

This study focuses on improving the scheduling of container-handling equipment such as quay cranes, yard cranes, and automated vehicles in automated container terminals. The objective is to reduce ship berthing time by coordinating different equipment during loading operations. The researchers developed a mixed-integer programming model along with an adaptive genetic algorithm to solve the scheduling problem. Experimental results showed that efficient coordination of cranes and vehicles can significantly improve terminal productivity. The study highlights the importance of advanced optimization models in automated terminal operations.

Luo, J., & Wu, Y. (2020). *Computers & Industrial Engineering*, 149, 106848.

Smart Port Concept: A Case Study Of Port-Integrated Autonomous Networks.

This study introduces the concept of Port-Integrated Autonomous Networks (PIAN), which combines blockchain technology, distributed artificial intelligence, and autonomous systems. The framework aims to support the digital transformation of seaports by improving operational efficiency and risk management. The research identifies key technological components such as sensor infrastructure, autonomous machinery, and secure digital platforms. It also discusses cybersecurity and regulatory considerations related to smart port development. The study provides a theoretical model that can guide ports toward sustainable and intelligent operations.

Melnyk, O., Onishchenko, O., Fomin, O., Yarovenko, V., Pavlova, N., Drozhzhyn, O., & Vyshnevsky, D. (2025). *Journal of Maritime Research*, 22(1), 315–323.

Smart Ports in Industry 4.0: A Systematic Literature Review

This paper reviews existing research on smart ports using the PRISMA systematic review framework. The study analyzes how technologies associated with Industry 4.0, such as IoT, cloud computing, big data, and cybersecurity, are transforming port operations. The findings highlight that smart ports improve operational efficiency, reduce costs, and enhance decision-making through data-driven systems. The review also identifies key research gaps and emerging trends in smart port development. Overall, the study emphasizes the growing importance of digital technologies in modern port management.

Paraskevas, A., Madas, M., Zeimpekis, V., & Fouskas, K. (2024). *Logistics*, 8(28).

Smart Warehousing as a Wave of the Future.

This study examines the concept of smart warehousing and its role in modern supply chains. The research highlights how Industry 4.0 technologies such as robotics, automation, and data analytics improve warehouse operations. Smart warehouses help organizations increase productivity, reduce operational costs, and improve supply chain responsiveness. The study also discusses how the COVID-19 pandemic accelerated the adoption of digital warehouse technologies. It concludes that smart warehousing plays an important role in improving overall supply chain efficiency.

Min, H. (2023). *Logistics*, 7(2), 30.

Strategic Analysis of the Automation of Container Port Terminals through BOT

This research introduces the Business Observation Tool (BOT) as a method for analyzing automation strategies in container port terminals. The tool helps port operators evaluate the impact of new technologies and digital systems on operational performance.

The study highlights that automation can improve efficiency and compliance with regulatory standards. It also provides a framework for decision-makers to assess environmental and operational conditions before implementing automation. The research contributes to the strategic planning of port digitalization initiatives.

Camarero Orive, A., Parra Santiago, J. I., Esteban-Infantes Corral, M. M., & González-Cancelas, N. (2020). Logistics, 4(1), 3

Automation in ports and labour relations in XXI Century

This study examines the economic and social implications of port automation, particularly its impact on employment. While automation improves operational efficiency and reduces labor costs for port operators, it may also lead to job displacement and changes in workforce structure. The research discusses the broader economic consequences, including tax impacts and social welfare costs. The study highlights the need for balanced strategies that consider both technological advancement and workforce sustainability.

Oliveira, H. S., & Varela, R. (n.d.).

Technological Forecasting & Social Change.

This study focuses on global climate policies and their impact on technological transitions in energy systems. It examines different climate action scenarios and their potential to limit global warming to 2°C. The research shows that delayed climate action increases reliance on negative-emission technologies and raises the risk of exceeding climate targets. The study emphasizes the importance of early technological and policy interventions for sustainable development.

Schaeffer, M., Gohar, L., Kriegler, E., Lowe, J., Riahi, K., & van Vuuren, D. P. (2015). Technological Forecasting & Social Change, 90, 257–268.

The internet of things for smart ports

This paper analyzes the role of Internet of Things (IoT) technologies in improving port operations. Using the Tangier Med Port as a case study, the research demonstrates how IoT applications enable real-time monitoring of ships, containers, and port equipment. These technologies improve operational efficiency, reduce manual processes, and enhance coordination among stakeholders. The study highlights IoT as a key component in the transition toward fully automated and digitalized ports.

Bouhlal, A., Aitabdelouahid, R., & Marzak, A. (2022). Procedia Computer Science, 203, 819–824.

The Re-Conceptualization of the Port Supply Chain as a Smart Port Service System.

This research proposes a new perspective on port supply chains by viewing them as smart service systems. The study applies the principles of service science to better understand the dynamics of seaport logistics. Using the Port of Salerno as an example, the authors explain how integrated digital systems can improve coordination among supply chain stakeholders. The research highlights the importance of collaboration, service integration, and technological innovation in building competitive port supply chains.

Botti, A., Monda, A., Pellicano, M., & Torre, C.

The future of automated ports.

This report explores the opportunities and challenges associated with port automation. It highlights that although automation adoption has been slower in ports compared to other industries, it is now accelerating due to technological advancements. Automated ports offer benefits such as improved safety, higher productivity, and reduced operational costs.

However, challenges include high investment requirements, lack of skilled personnel, and complex data management systems. The report predicts that automation will lead to the development of “Port 4.0,” where ports act as integrated service platforms rather than simple infrastructure providers.

Chu, F., Gailus, S., Liu, L., & Ni, L. (2018).

Enabling AI-based Integration, Digitalization, and Smart Automation of Industrial Parks and Robotic Warehouses.

This study discusses how artificial intelligence and digital technologies can improve logistics operations in industrial parks and warehouses. The authors propose the concept of Smart Industrial Parks (SIPs), which integrate digital platforms, robotic systems, and shared logistics facilities. The research also highlights the use of digital twins and cloud-based manufacturing systems to optimize resource allocation and operational efficiency. The framework supports the development of intelligent logistics ecosystems aligned with Industry 4.0 initiatives.

Shaurya, S., Palkar, P., & Srivastava, A. (2023).

Port hinterland connectivity

This research examines the importance of hinterland connectivity in improving port competitiveness. While port infrastructure and vessel turnaround times have improved, inland transport connections often remain inefficient. The study highlights challenges such as coordination between multiple stakeholders and limitations in transport infrastructure. Strong port-hinterland connectivity is essential for efficient cargo movement and overall supply chain performance.

Merk, O., & Notteboom, T. (2015).

Port logistic issues and challenges in the Industry 4.0 era for emerging economies.

This study analyzes the challenges faced by port logistics systems in emerging economies, particularly in the context of Industry 4.0. The research identifies issues related to cargo handling, customs clearance, storage, transportation, and regulatory coordination. Using Soft System Methodology (SSM), the study develops a conceptual framework to address these challenges. The proposed model aims to improve transparency, reduce delays, and enhance coordination among different stakeholders involved in port logistics.

Sarkar, B. D., Shankar, R., & Kar, A. K. (2023).

Objectives

1. To assess the impact of automation, digitisation, and digitalisation on turnaround time, cargo throughput, and intermodal connectivity across rail, road, and water transport.
2. To analyse smart port technologies enhance supply chain resilience through adaptive and real-time port operations.
3. To evaluate the role of technologies like automated cranes and smart warehousing in improving multimodal transport integration within Indian ports.

Objective 1 focuses on evaluating how **automation, digitization, and digitalization** impact key performance indicators like turnaround time, cargo throughput, and multimodal connectivity. Technologies such as optical character recognition (OCR) scanners at gates, terminal operating systems (TOS), and real-time data platforms have demonstrated substantial improvements in reducing bottlenecks and improving coordination among shipping lines, customs, and inland transport providers (Acciaro, Ghiara, & Cusano, 2014).

With these technologies, ports can improve their **Port Performance Index**, lower waiting times, and improve customer satisfaction.

Objective 2 addresses the growing need for **supply chain resilience**—a concept that gained sharp relevance during the COVID-19 pandemic. Ports that had already adopted digital tools such as remote operations, AI-enabled scheduling, and digital documentation were better able to maintain throughput despite labour shortages and movement restrictions (UNCTAD, 2021). Smart ports enable adaptive and real-time responses to disruptions, whether they arise from global crises, natural disasters, or localized congestion.

Objective 3 explores the role of **automated cranes and smart warehousing** in enhancing **multimodal transport integration**. Automated cranes improve handling speed and accuracy, reducing vessel berth time and accelerating cargo transfer to rail and road networks. Smart warehouses—equipped with RFID scanning, temperature control, and real-time inventory tracking—enhance the efficiency of cargo storage, reduce spoilage, and support just-in-time logistics. These innovations are particularly relevant in Indian ports such as Mundra and JNPT, where efforts to digitise customs, expand rail connectivity, and modernise storage facilities are already underway (Adani Ports & SEZ, 2023; JNPT, 2023).

Formulation of Hypothesis

Hypothesis of objective 1

H0: There is no significant relation between adoption of automation, digitisation, and digitalisation on turnaround time, cargo throughput, and intermodal connectivity across rail, road, and water transport.

H1: There is a significant relationship between adoption of automation, digitisation, and digitalization and turnaround time, cargo throughput, and intermodal connectivity across rail, road, and water transport.

Hypothesis of objective 2

H0: There is no significant relation between smart port technologies that enhance supply chain resilience through adaptive and real-time port operations.

H1: There is a significant relationship between smart port technologies that enhance supply chain resilience through adaptive and real-time port operations.

Hypothesis of objective 3

H0: There is no significant relation between the role of technologies like automated cranes and smart warehousing in improving multimodal transport integration within Indian ports.

H1: There is a significant relationship between the role of technologies like automated cranes and smart warehousing in improving multimodal transport integration within Indian ports.

Research Methodology

Exploratory Research design

According to **Harvard Catalyst**, a program from Harvard University, mixed methods research "strategically integrates or combines rigorous quantitative and qualitative research methods to draw on the strengths of each" (Harvard Catalyst, n.d.). This approach is particularly useful for complex questions in fields like health, education, and social sciences, where a broader perspective is needed.

Creswell, J. W., & Plano Clark, V. L. (2018). Designing and conducting mixed methods research (3rd ed.). Sage.

Mixed Research design

Definition: Research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of inquiry."

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and Conducting Mixed Methods Research* (3rd ed.). SAGE Publications. (Often cited via earlier editions as well).

Sources Of Data

Primary Data: Will be collected from the questionnaire.

Secondary Data Only: Peer-reviewed academic journals (Scopus, Web of Science, ScienceDirect, Springer, MDPI).

Case studies on ports such as Vizhinjam, JNPT, Rotterdam, Yangshan, and Los Angeles.

Policy and industry reports from IMO, UNCTAD, OECD, World Bank, Ministry of Ports (India).

Technical reports on automation, cold storage, digitalisation, and multimodal integration

Target Population

- **Element:** These are the individual units or objects about which information is desired for example a respondent survey.
 - Port authorities and managers (operations, planning, IT/automation).
 - shipping line representatives, freight forwarders, and logistics managers.
 - Terminal operators and customs officials.
 - suppliers of technology (digital systems, automation, and warehousing).
 - suppliers of inland transportation (road/rail link).
- **Sampling Unit:** Individual experts and institutions engaged in logistics, automation, and port operations.
- **Geographic Scope:** Mainly Indian ports (**JNPT, Vizhinjam, JM Baxi Kandla port , Mumbai Port and Mundra Port**), with benchmarking from top ports worldwide.
- **Time:** August 2025-26.

Sampling Frame

Secondary research sources for the sampling frame include industry repositories (**IMO, UNCTAD, OECD, World Bank**, and port authority publications) and academic databases (Scopus, Web of Science, ScienceDirect, Springer, and MDPI).

Upcoming Survey: Ports, logistics/shipping firms, and trade bodies (**Container Shipping Lines Association and Federation of Freight Forwarders**) have employee records.

Sampling Techniques

- Purposive sampling, which chooses only pertinent research papers and case studies, is used for secondary data.
- **For Future Questionnaire:**
 - **Purposive Sampling** – targeting only stakeholders directly involved in port automation and logistics.

- **Stratified Sampling** – ensuring representation from different categories (port authority, shipping, logistics, customs, technology).

Sample size

- Secondary Data: Approximately 100-120 high-quality papers/reports to provide global and Indian perspectives as well as the foreign countries reports papers.
- Regarding the Future Questionnaire
- Overall, between 100 and 120 responders (a balanced mix from both Vizhinjam, JNPT, JM Baxi Kandla port, Agency operation companies).
- Proposed dissection:
 - 25–30 port managers and authorities.
 - 25–30 transport and logistics operators.
 - 20–25 freight forwarders and shipping agencies.
 - 15–20 terminal/customs workers.
 - 15-20 students for the education purpose.

Discussion

Data Analysis on Primary Data

The primary data for this study was collected from 105 respondents through a structured questionnaire using a 5-point Likert scale, where 1 represents Strongly Disagree and 5 represents Strongly Agree. For the purpose of statistical analysis, Regression was conducted which helped in identifying respondents' opinions.

1. To assess the impact of automation, digitisation, and digitalisation on turnaround time, cargo throughput, and intermodal connectivity across rail, road, and water transport.

Hypothesis of objective 1

H0: There is no significant relation between adoption of automation, digitisation, and digitalisation on turnaround time, cargo throughput, and intermodal connectivity across rail, road, and water transport.

H1: There is a significant relationship between adoption of automation, digitisation, and digitalisation on turnaround time, cargo throughput, and intermodal connectivity across rail, road, and water transport.

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26.202	4	6.550	215.406	.000 ^b
	Residual	1.916	63	.030		
	Total	28.118	67			

a. Dependent Variable: Automation effect on TAT

b. Predictors: (Constant), Water logistics coordination, Road linkage improvement, Rail connectivity improvement, Cargo throughput improvement

Objective

Analysis

The ANOVA regression analysis was carried out to understand how logistics coordination and better connectivity influence automation efficiency in reducing turnaround time (TAT). The results show a **p-value of 0.000**, which is **lower than the significance level of 0.05**, indicating that the model is statistically significant. Hence, the **Null Hypothesis (H_0) is rejected and the Alternate Hypothesis (H_1) is accepted**. This means that improved logistics coordination and stronger multimodal connectivity play an important role in increasing automation efficiency and reducing turnaround time in port operations.

This result is supported by the studies discussed in the literature review. **Heilig & Voß (2017)** explained that digitalization and automation help ports improve operational efficiency. In addition, **Molavi et al. (2020)** stated that better multimodal connectivity helps ports reduce operational delays and improve overall performance.

2. To analyse smart port technologies enhance supply chain resilience through adaptive and real-time port operation.

Hypothesis of objective 2

H_0 : There is no significant relation between smart port technologies that enhance supply chain resilience through adaptive and real-time port operations.

H_1 : There is a significant relationship between smart port technologies that enhance supply chain resilience through adaptive and real-time port operations.

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15.459	3	5.153	43.060	.000 ^b
	Residual	7.659	64	.120		
	Total	23.118	67			

a. Dependent Variable: Real time alerts

b. Predictors: (Constant), IoT monitoring, Digital twin decision making, Automated scheduling

Analysis

The ANOVA regression analysis was conducted to examine the impact of smart port technologies on real-time operational alerts. The results indicate a **p-value of 0.000**, which is **less than the acceptable significance level of 0.05**, showing that the regression model is statistically significant. Therefore, the **Null Hypothesis (H_0) is rejected and the Alternate Hypothesis (H_1) is accepted**. This suggests that the use of smart technologies in ports significantly improves real-time monitoring and enables faster operational alerts.

These findings are consistent with the literature review. **Heilig, Schwarze & Voß (2017)** highlighted that digital technologies such as IoT and automation support better monitoring and decision-making in port operations. Similarly, **Tijan et al. (2021)** noted that smart port systems allow real-time data sharing and improve operational visibility.

2. To evaluate the role of technologies like automated cranes and smart warehousing in improving multimodal transport integration within Indian ports.

Hypothesis of objective 3

H0: There is no significant relation between the role of technologies like automated cranes and smart warehousing in improving multimodal transport integration within Indian ports.

H1: There is a significant relationship between the role of technologies like automated cranes and smart warehousing in improving multimodal transport integration within Indian ports.

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19.886	4	4.972	38.050	.000 ^b
	Residual	8.231	63	.131		
	Total	28.118	67			

a. Dependent Variable: Transport integration

b. Predictors: (Constant), Need for improvement, Smart warehousing storage, Automated cranes efficiency, Technology contribution

Analysis

The ANOVA regression analysis was performed to analyze the role of automation technologies in improving transport integration. The results show a **p-value of 0.000**, which is **below the significance level of 0.05**, indicating that the regression model is statistically significant. As a result, the **Null Hypothesis (H₀) is rejected and the Alternate Hypothesis (H₁) is accepted**. This indicates that automation technologies help strengthen coordination between port operations and inland transport systems, leading to more efficient logistics and supply chain performance.

This outcome is supported by the studies included in the literature review. **Notteboom & Rodrigue (2005)** discussed how technological advancements improve port–hinterland connectivity. Furthermore, **Molavi et al. (2020)** emphasized that automation and smart technologies enhance multimodal transport integration and overall supply chain efficiency.

Conclusion

The growing complexity of global trade has made it necessary for traditional seaports to evolve into smart and digitally connected logistics hubs. This study explored how automation, digitisation, and digitalisation influence port efficiency and supply chain resilience, particularly in the context of Indian ports. The analysis indicates that the adoption of smart port technologies can significantly improve operational performance by reducing vessel turnaround time, increasing cargo throughput, and strengthening coordination between different transport modes such as rail, road, and inland waterways.

Modern technologies including automated cranes, smart warehousing systems, IoT-based monitoring, and digital port community platforms help ports manage their operations more effectively. These systems allow real-time data sharing among stakeholders and support better decision-making, which ultimately improves transparency and operational reliability. As a result, ports are gradually transforming into intelligent logistics nodes that play a crucial role in global supply chains. The experience of the COVID-19 pandemic also showed that ports with stronger digital systems were better able to maintain operations and

respond to disruptions, highlighting the importance of technological integration for building resilient supply chains.

Despite these benefits, the research also identifies several challenges that slow down the large-scale adoption of smart port technologies. High implementation costs, difficulties in integrating systems among different stakeholders, cybersecurity risks, and the need for a skilled workforce remain key concerns. Overcoming these issues will require coordinated efforts from policymakers, port authorities, and industry stakeholders through strategic investments, supportive policies, and training initiatives.

In the Indian maritime sector, ongoing initiatives such as port modernization programs, digital customs systems, and infrastructure development provide a strong base for the adoption of smart port frameworks. Improving digital infrastructure and strengthening multimodal connectivity will be important for enhancing trade competitiveness and reducing logistics costs in the future. Overall, the transition toward smart and integrated port management represents an important step in improving efficiency, sustainability, and resilience in maritime logistics. Further research can focus on detailed case studies and empirical performance data from Indian ports to better understand the long-term impact of digital transformation on port operations and international trade.

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List of Abbreviations

5G	–	Fifth Generation Mobile Network
ACAAI	–	Air Cargo Agents Association of India
ACT	–	Automated Container Terminals
AFMS	–	Autonomous Fleet Management System
AGV	–	Automated Guided Vehicle
AI	–	Artificial Intelligence
AIS	–	Automatic Identification System
AM	–	Allocation Model
ANOVA	–	Analysis of Variance
APM	–	Automated Port Management
APMC	–	Agricultural Produce Market Committee
ARCH	–	Autoregressive Conditional Heteroskedasticity
ARIMA	–	Autoregressive Integrated Moving Average
ARIMARCH	–	Autoregressive Integrated Moving Average with ARCH
ARMA	–	Autoregressive Moving Average
AS/RS	–	Automated Storage and Retrieval System
ASC	–	Automated Stacking Crane
BAF	–	Bunker Adjustment Factor
BBM	–	Black Box Model
BDI	–	Baltic Dry Index
BESS	–	Battery Energy Storage System
BIMCO	–	Baltic and International Maritime Council
BOOT	–	Build Own Operate Transfer
BOT	–	Build Operate Transfer
CAPEX	–	Capital Expenditure
CAX	–	Container Availability Index
CFS	–	Container Freight Station
CII	–	Carbon Intensity Indicator
CII	–	Confederation of Indian Industry
CISF	–	Central Industrial Security Force
CNRS	–	Container Number Recognition System
CO ₂	–	Carbon Dioxide
CoT	–	Cloud of Things
COVID-19	–	Coronavirus Disease 2019

CSR	–	Corporate Social Responsibility
CV	–	Coefficient of Variation
DBFOT	–	Design Build Finance Operate Transfer
DEA	–	Data Envelopment Analysis
DFC	–	Dedicated Freight Corridor
DMIC	–	Delhi–Mumbai Industrial Corridor
DMO	–	Decentralized Maritime Operations
DPA	–	Deendayal Port Authority
DT	–	Digital Twin
DT	–	PdM – Digital Twin-based Predictive Maintenance
DTT	–	Digital Twin Technology
e-BL / e-BLs	–	Digital bills of lading / electronic Bills of Lading
ECR	–	Empty Container Repositioning
EDI	–	Electronic Data Interchange
EEXI	–	Energy Efficiency Existing Ship Index
EMAS	–	Eco-Management and Audit Scheme
EMR	–	Electronic Maritime Records
EMS	–	Energy Management System
EMS	–	Environmental Management System
ESS	–	Energy Storage System
EU	–	European Union
EXIM	–	Export-Import
FAO	–	Food and Agriculture Organization
FCL	–	Full Container Load
FEU	–	Forty-foot Equivalent Unit
FF	–	Freight Forwarder
FMC	–	Federal Maritime Commission
FRM	–	Fast-Running Model
FSSAI	–	Food Safety and Standards Authority of India
FY	–	Fiscal Year
GDP	–	Gross Domestic Product
GHG	–	Greenhouse Gas
GIS	–	Geographic Information System
GMB	–	Gujarat Maritime Board
GPS	–	Global Positioning System
HEGY	–	Hylleberg-Engle-Granger-Yoo

HKC	–	Hong Kong Convention
HRM	–	Human Resource Management
IaaS	–	Infrastructure as a Service
IAEA	–	International Atomic Energy Agency
IATA	–	International Air Transport Association
IBM	–	International Business Machines
ICD	–	Inland Container Depot
ICT	–	Indian Container Terminal
ICT	–	Information and Communication Technology
IHM	-	Inventory of Hazardous Materials
IMO	–	International Maritime Organization
IoT	–	Internet of Things
ISM	–	Interpretive Structural Modeling
ISO	–	International Organization for Standardization
ITF	–	International Transport Forum
JNPT	–	Jawaharlal Nehru Port Trust
KPI	–	Key Performance Indicator
LNG	–	Liquefied Natural Gas
LPI	–	Logistics Performance Index
MASS	–	Maritime Autonomous Surface Ships
MbPA	–	Mumbai Port Authority
MDPI	–	Multidisciplinary Digital Publishing Institute
MDTA	–	Maritime Digital Twin Architecture
MET	–	Maritime Education and Training
MICN	–	Marine Integrated Communication Network
MICT	–	Mumbai International Cruise Terminal
ML	–	Machine Learning
MLC	–	Maritime Labour Convention
MMLP	–	Multimodal Logistics Park
MSME	–	Micro, Small and Medium Enterprises
MS-VAR	–	Markov-Switching Vector Autoregression
NDH-SP	–	Network Design Heuristic-Shortest Path Model
NLP	–	National Logistics Policy
NOC	–	Non-Officer Crew
NOx	–	Nitrogen Oxides
NVOCC	–	Non-Vessel Operating Common Carrier

O&M	–	Operation and Maintenance
OCR	–	Optical Character Recognition
OECD	–	Organisation for Economic Co-operation and Development
OPS	–	Onshore Power Supply
PaaS	–	Platform as a Service
PAHs	–	Polycyclic Aromatic Hydrocarbons
PCB	–	Polychlorinated Biphenyls
PCS	–	Port Community System
PdM	–	Predictive Maintenance
PdMDT	–	Predictive Maintenance based on Digital Twin
PPE	–	Personal Protective Equipment
PPP	–	Public Private Partnership
PRISMA	–	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PV	–	Photovoltaic
QA	–	Quality Assurance
RBF	–	Radial Basis Function
RFID	–	Radio Frequency Identification
RL	–	Reinforcement Learning
RL	–	Reverse Logistics
RMCG	–	Rail Mounted Gantry Crane
ROI	–	Return on Investment
RTG	–	Rubber Tyred Gantry Crane
SaaS	–	Software as a Service
SCFI	–	Shanghai Containerized Freight Index
SCFI	–	Shanghai Containerized Freight Index
SCM	–	Supply Chain Management
SD	–	Standard Deviation
SDGs	–	Sustainable Development Goals
SDT	–	Ship's Digital Twin
SEM	–	Structural Equation Modelling
SEZs	–	Special Economic Zones
SHM	–	Structural Health Monitoring
SME	–	Small and Medium Enterprises
SOP	–	Standard Operating Procedures
SOx	–	Sulphur Oxides

SPL-VA	–	Shortest Path Location – Value Allocation Model
SSM	–	Soft System Methodology
TAM	–	Technology Acceptance Model
TAT	–	Turnaround Time
TCE	–	Time Charter Equivalent
TEU	–	Twenty-foot Equivalent Unit
THC	–	Terminal Handling Charge
TOS	–	Terminal Operating System
UAV	–	Unmanned Aerial Vehicle
ULCS	–	Ultra Large Container Ship
UN	–	United Nations
UNCTAD	–	United Nations Conference on Trade and Development
UWSNs	–	Underwater Sensor Networks
VAR	–	Vector Auto regression
VCP	–	Virtual Container Pool
VLCC	–	Very Large Crude Carrier
VLGC	–	Very Large Gas Carrier
VLSFO	–	Very Low Sulphur Fuel Oil
VTs	–	Vessel Traffic System
WBM	–	Weather-Based Model
WCI	–	World Container Index
WMS	–	Warehouse Management System
WTO	–	World Trade Organization

About Editors

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Dr. Tanuja Kaushik serves as the Professor and Dean Academic Affairs at Gujarat Maritime University with over 24 years of experience in academic leadership, research, and program management. She has experience in academic governance, strategic leadership and multidisciplinary program management. A multi award-winning educator, she received multiple awards including Woman Achiever of the Year 2025, Edupreneur Director of the Year 2023, Ambassador of Green Planet Award 2022, Most Inspiring Educator 2022 and Best Mentor of the Year 2021. Dr. Kaushik has contributed to executive education by delivering Management Development Programs for executives from Navratna and Miniratna organizations and is recognized for her expertise in Decision Modelling, Optimization, and Entrepreneurship through workshops conducted with PHDCCI and Konrad Adenauer Stiftung (KAS), Germany. She has delivered expert sessions on Research Methodology and Data Analytics at institutions and presented research at premier institutes including IIMs, IITs, FMS, MDI, IMT, FORE, and AIMA, with publications in reputed journals. She mentors Ph.D. scholars, with 13 awarded under her guidance, and actively serves on academic bodies including Board of Management, Academic Council, and Board of Studies. She holds a Ph.D. in Management along with postgraduate degrees and an Executive Program from IIT Delhi.

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