PROJECT REPORT

A Study on Analysing and Improving Dwell Time of Containers at Indian Ports

Submitted to the School of Maritime Management, Indian Maritime University in Partial fulfilment for the requirements for the award of the degree of MBA in

International Transportation and Logistics Management

by

SIJI SAIRAM

(2303305038)

Under the supervision of,

Dr. Emil Mathew

Assistant Professor, SMM

SCHOOL OF MARITIME MANAGEMENT

INDIAN MARITIME UNIVERSITY

(A Central University, Government of India)

CHENNAI CAMPUS

May 2025

DECLARATION

I, **SIJI SAIRAM**, **Reg. No. 2303305038** student of **School of Maritime Management**, **Indian Maritime University**, pursuing **MBA in International Transportation and Logistics Management** hereby declare that the submission of this project report titled **"A Study on Analysing and Improving Dwell Time of Containers at Indian Ports"** has been prepared by me towards the partial fulfilment of the Master of Business Administration in International Transportation and Logistics Management under the supervision of **Dr . Emil Mathew,** Assistant Professor, SMM, Indian Maritime University, Chennai Campus. I also declare that this project report is my original work and has not been copied from any other report previously submitted for the award of any degree, fellowship, or other in similar title.

Place: Chennai

Date: 28.05.2025

SIJI SAIRAM

2303305038

CERTIFICATE

This is to certify that the project report entitled **"A Study on Analysing and Improving Dwell Time of Containers at Indian Ports"** submitted to School of Maritime Management, Indian Maritime University, Chennai Campus, in partial fulfilment for the award of the degree of Master of Business Administration (MBA) in International Transportation and Logistics Management, is a record work carried out entirely by **Siji Sairam**, Reg. No.**2303305038.**

Dr. Emil Mathew

Project Guide

28-5-25

External Examiner:

Place: Chennai

Date: 28-5-25

ACKNOWLEDGEMENT

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

I would like to thank my parents for the moral support and cooperation throughout the programme. My heartfelt and sincere thanks to, **Dr. B Swaminathan**, Associate professor, Head SMM, Indian Maritime University, Chennai Campus who gave me the golden opportunity to do this wonderful project on the topic "**A Study on Analysing and Improving Dwell time of Containers at Indian Ports**". I pay him my deep sense of gratitude for guiding me.

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

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

SIJI SAIRAM

ABSTRACT

The performance of port infrastructure plays a pivotal role in determining the efficiency and competitiveness of a nation's logistics and supply chain ecosystem. One of the most critical indicators of this performance is container dwell time, the total time a container remains within the port premises before it is cleared for further movement. High dwell time not only results in congestion and inefficiencies but also escalates costs for port users and undermines India's position in global maritime trade rankings. This study aims to comprehensively analyse container dwell time across major Indian ports over the past six years, focusing on identifying the key factors contributing to delays and proposing evidence-based strategies for improvement. The research leverages secondary data from government and international sources, including NICDC Logistics Data Services, the Ministry of Ports, Shipping and Waterways, Indian Ports Association, UNCTAD, and the World Bank, to examine patterns and benchmark Indian ports against global standards.

Findings reveal a range of systemic issues, including inadequate infrastructure, lack of coordination between port stakeholders, delayed documentation processes, and inefficiencies in multimodal connectivity. Informed by these insights, the study puts forward a set of targeted recommendations to reduce dwell time, such as implementing advanced Port Community Systems (PCS), streamlining customs procedures through digitization, enhancing real-time cargo tracking, optimizing yard and berth utilization, and fostering inter-agency collaboration. The study also aligns its recommendations with national policy frameworks like the Maritime India Vision 2030 and the Maritime Amrit Kaal Vision 2047, emphasizing the strategic importance of port modernization in India's economic growth. By improving dwell time, Indian ports can not only enhance operational efficiency and reduce logistics costs but also attract more transshipment business and improve their global ranking in maritime performance indices.

TABLE OF CONTENTS

DECLARATION i
CERTIFICATE i
ACKNOWLEDGEMENT iii
ABSTRACT iv
LIST OF TABLES vii
LIST OF FIGURES viii
ABSTRACT ix

CHAPTER 1 INTRODUCTION 1

1.1 Background of the Study 2
1.2 Statement of the Problem 3
1.3 Research Objectives 4
1.3.1 General Objective: 4
1.3.2 Specific Objectives: 4
1.4 Research Questions 5
1.5 Significance of the Study 5
1.6 Scope of the Study 6
1.6.1 Global and National Initiatives 7
1.6.2 Delimitations of the Study 8
1.7 Limitations of the Study 8
1.8 Organization of the Study 9

CHAPTER 2 LITERATURE REVIEW 11

2.1 Introduction 12
2.2 Concept of Container Dwell Time 12
2.3 Factors Influencing Dwell Time at Ports 12
2.4 International Best Practices and Benchmarks 13
2.5 Review of Studies on Indian Ports 14
2.6 Conceptual Framework 14
2.7 Empirical Review 14
2.8 Critique of Existing Literature 15
2.9 Research Gaps Identified 15

CHAPTER 3 RESEARCH METHODOLOGY 17

3.1 Research Design 18
3.2 Sources of Data 18
3.3 Data Collection Methods 19
3.4 Tools and Techniques for Data Analysis 19
3.5 Limitations of the Methodology 20
3.6 Ethical Considerations 20

CHAPTER 4 DATA ANALYSIS 21

4.1. Overview of Data Collected 22
4.2 Trends in Container Dwell Time at Major Indian Ports 22
4.2.1 Port-wise Comparative Analysis 22
4.2.2 Year-wise Trend Analysis 22
4.3 Forecasting Dwell Time Using Linear Regression in R 24
4.4 Correlation Between Container Volume Distribution and Dwell Time 33
4.5 Summary of Data Interpretation 36

CHAPTER 5 FINDINGS AND RECOMMENDATIONS 38

5.1 Introduction 39
5.2 Key Findings 39
5.3 Port-Specific Findings and Recommendations 39
5.4 Strategic Recommendations for Reducing Container Dwell Time Across Indian Ports 44
5.5 Summary of Port-Specific Recommendations 46
5.6 Conclusion 46

CHAPTER 6 CONCLUSION 48

REFERENCES 51

BIBLIOGRAPHY 53

LIST OF TABLES

TABLE 1 IMPORT AND EXPORT DWELL TIME OF VARIOUS PORTS FROM 2019 TO 2024 23
TABLE 2 CONTAINER VOLUME DISTRIBUTION AND DWELL TIME OF 2024 33
TABLE 3 SUMMARY OF RECOMMENDATIONS 46

LIST OF FIGURES

FIGURE 1 IMPORT-EXPORT CONTAINER VOLUME IN TEUS 23
FIGURE 2 DWELL TIME FORECAST FOR JNPA FROM 2019 TO 2029 24
FIGURE 3 DWELL TIME FORECAST FOR MUNDRA FROM 2019 TO 2029..... 25
FIGURE 4 DWELL TIME FORECAST FOR PIPAVAV FROM 2019 TO 2029 25
FIGURE 5 DWELL TIME FORECAST FOR KANDLA FROM 2019 TO 2029 26
FIGURE 6 DWELL TIME FORECAST FOR CHENNAI FROM 2019 TO 2029 26
FIGURE 7 DWELL TIME FORECAST FOR HAZIRA FROM 2019 TO 2029 27
FIGURE 8 DWELL TIME FORECAST FOR KOCHI FROM 2019 TO 2029..... 27
FIGURE 9 DWELL TIME FORECAST FOR KATTUPALLI FROM 2019 TO 2029 ... 28
FIGURE 10 DWELL TIME FORECAST FOR TUTICORIN FROM 2019 TO 2029.... 28
FIGURE 11 DWELL TIME FORECAST FOR ENNORE FROM 2019 TO 2029 29
FIGURE 12 DWELL TIME FORECAST FOR NEW MANGALORE FROM 2019 TO 2029 29
FIGURE 13 DWELL TIME FORECAST FOR VISAKHAPATNAM FROM 2019 TO 2029 30
FIGURE 14 DWELL TIME FORECAST FOR KOLKATA FROM 2019 TO 2029..... 30
FIGURE 15 DWELL TIME FORECAST FOR HALDIA FROM 2019 TO 2029 31
FIGURE 16 IMPORT VOLUME DISTRIBUTION FOR 2024 33
FIGURE 17 EXPORT VOLUME DISTRIBUTION FOR 2024..... 34
FIGURE 18 CORRELATION PLOT OF VOLUME DISTRIBUTIONAND DWELL TIME OF 2024..... 35

ABSTRACT

The performance of port infrastructure plays a pivotal role in determining the efficiency and competitiveness of a nation's logistics and supply chain ecosystem. One of the most critical indicators of this performance is container dwell time, the total time a container remains within the port premises before it is cleared for further movement. High dwell time not only results in congestion and inefficiencies but also escalates costs for port users and undermines India's position in global maritime trade rankings. This study aims to comprehensively analyse container dwell time across major Indian ports over the past six years, focusing on identifying the key factors contributing to delays and proposing evidence-based strategies for improvement. The research leverages secondary data from government and international sources, including NICDC Logistics Data Services, the Ministry of Ports, Shipping and Waterways, Indian Ports Association, UNCTAD, and the World Bank, to examine patterns and benchmark Indian ports against global standards.

Findings reveal a range of systemic issues including inadequate infrastructure, lack of coordination between port stakeholders, delayed documentation processes, and inefficiencies in multimodal connectivity. Informed by these insights, the study puts forward a set of targeted recommendations to reduce dwell time, such as implementing advanced Port Community Systems (PCS), streamlining customs procedures through digitization, enhancing real-time cargo tracking, optimizing yard and berth utilization, and fostering inter-agency collaboration. The study also aligns its recommendations with national policy frameworks like the Maritime India Vision 2030 and the Maritime Amrit Kaal Vision 2047, emphasizing the strategic importance of port modernization in India's economic growth. By improving dwell time, Indian ports can not only enhance operational efficiency and reduce logistics costs but also attract more transshipment business and improve their global ranking in maritime performance indices.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In the global marine supply chain, ports serve as essential hubs that allow the transportation of commodities from producers to consumers across continents Among the several performance criteria used to evaluate port efficiency, container dwell time is one of the most important indications. It reflects the operational fluidity of a port, the coordination among stakeholders, and the effectiveness of customs and regulatory processes. Furthermore, global shipping trends have demonstrated that ports implementing digital twin technologies and AI-based port community systems are achieving container dwell times of less than 48 hours. Singapore, for example, through its Next Generation Port initiatives, has consistently achieved sub-2-day dwell times across most container categories.

The UNCTAD Review of Maritime Transport (2023) emphasizes the growing importance of digital transformation and data-driven governance in reducing port inefficiencies and enhancing supply chain resilience, particularly in light of disruptions from the COVID-19 pandemic and geopolitical uncertainties. Moreover, the World Bank's Logistics Performance Index (LPI**)** and the Time Release Study (TRS) framework by the World Customs Organization (WCO) highlight dwell time as a critical bottleneck in border clearance and multimodal connectivity. Countries with lower container dwell times consistently rank higher in the LPI, indicating strong trade facilitation measures.

In India, projects like Bharatmala and the Dedicated Freight Corridors (DFCs) are expected to further reduce container dwell times by improving last-mile connectivity and creating multimodal logistics parks adjacent to major ports. However, actual implementation remains uneven, with East Coast ports still facing significant evacuation delays.

Containerization has revolutionized international trade, significantly enhancing efficiency in cargo transportation. According to the United Nations Conference on Trade and Development (UNCTAD 2023), ports are essential nodes in the global supply chain, facilitating over 80% of global product trade by volume and over 70% by value. Within this operational framework, container dwell time, the period a container remains within a port terminal before being moved, serves as a key indicator of port efficiency and logistical performance. In the context of India, a country experiencing exponential

growth in international trade, dwell time plays a pivotal role. India's port infrastructure consists of 12 main ports and over 200 non-major ports, which handle more than 95% of India's foreign commerce volume and 70% by value. However, despite continuous modernization and investment under schemes such as the Sagarmala Project, many Indian ports still exhibit higher dwell times compared to global benchmarks, undermining port competitiveness. Emerging economies in Asia are investing heavily in port-centric logistics models. Vietnam’s deep-water ports at Cai Mep-Thi Vai have reported container dwell time reductions by 25% after public-private partnerships restructured port operations.

According to the World Bank's Logistics Performance Index (LPI) 2023, India ranks 38th out of 139 nations, an increase over its 2018 ranking. Yet, average container dwell times at Indian ports, ranging from 3 to 7 days, continue to be longer than in global best-performing ports such as Singapore or Rotterdam, where dwell times are often less than 48 hours. This discrepancy underscores a significant need for systemic intervention.

1.2 Statement of the Problem

In the globalized trade environment, container ports serve as vital interfaces between sea and land transport. For India, a country striving to become a global manufacturing and export powerhouse under initiatives like Make in India and PM Gati Shakti, efficient port operations are non-negotiable. Among various port performance indicators, container dwell time is a critical metric influencing turnaround time, trade competitiveness, and logistics costs.

Despite concerted efforts through initiatives such as Sagarmala, PCS 1x, and Maritime India Vision 2030, container dwell time at major Indian ports remains significantly higher than international benchmarks. While Indian ports have undergone significant development in recent years, including infrastructure upgrades, digitization efforts, and implementation of facilitative government policies, challenges related to long container dwell times persist. While global ports like Singapore, Shanghai, and Rotterdam record average dwell times of 18 to 36 hours, Indian ports such as JNPA and Chennai often experience dwell times ranging from 72 hours to 7 days, depending on cargo type and customs clearance delays. Compared to global averages, dwell times at Indian ports remain high, indicating inefficiencies that hamper cargo throughput and overall supply chain fluidity.

Several factors contribute to this persistent issue. Inefficient cargo clearance procedures, lack of coordination among port stakeholders (such as customs, terminal operators, shipping lines, and freight forwarders), and delays in hinterland connectivity all add to prolonged container stays. These inefficiencies translate into tangible economic losses. Exporters and importers bear the brunt through increased demurrage and storage costs, while ports face congestion and reduced operational turnover. Additionally, inconsistent data reporting and the lack of uniform benchmarks across ports complicate the identification of performance gaps. Some ports may show improved dwell times due to better coordination, while others lag due to systemic issues. Understanding these variations is vital for developing tailored improvement strategies.

The implications are manifold: higher dwell time leads to congestion at port terminals, increased logistics costs, and delays in delivery schedules, which in turn impact export-import (EXIM) competitiveness. According to World Bank and NITI Aayog estimates, India's logistics costs amount to 14% of GDP, much higher than the global average of 8–10%, a major barrier for trade facilitation.

The problem is further exacerbated by the increasing pressure on Indian ports to handle higher cargo volumes due to India's growing trade activity. If container dwell time remains high, it will undermine the competitiveness of Indian ports on a global scale. This study, therefore, addresses a critical gap by undertaking a data-driven analysis of historical dwell time trends to identify root causes and propose improvements.

1.3 Research Objectives

1.3.1 General Objective:

The primary goal of this research is to study and analyze the trends in container dwell time at Indian ports using historical data and to propose actionable strategies for improvement.

1.3.2 Specific Objectives:

1. To analyze the trend of container dwell time across Indian ports over the last six years using credible datasets from government agency such as NICDC Logistics Data Services Ltd (NLDS).
2. To identify patterns, bottlenecks and performance variations across different ports.

By achieving these objectives, the study will provide a holistic understanding of the dwell time challenge and offer actionable insights for port authorities, policymakers, and logistics stakeholders.

1.4 Research Questions

To effectively solve the research topic, the study is led by the following main questions:

1. What are the average container dwell times at major Indian ports over the last six years?
   This question seeks to understand the current state of container dwell time in ports. It sets the baseline for analysis and helps assess the performance trajectory over time.
2. What are the primary factors contributing to prolonged container dwell time in Indian ports?
   This explores both internal and external factors, including port operations, customs clearance, inter-agency delays, digital integration issues, and hinterland connectivity.
3. What strategic recommendations can be proposed to improve dwell time and enhance India's port logistics ecosystem?
   This seeks to build on the insights gained to propose a forward-looking strategy aimed at systemic and operational reforms.

These questions will shape the research methodology and provide a logical framework for analysis and discussion. These questions will ensure that the study remains focused, relevant, and grounded in realistic improvements suited for the current Indian port environment.

1.5 Significance of the Study

The research holds substantial significance for multiple stakeholders in India's maritime and logistics ecosystem. Efficient port operations are central to economic growth, trade competitiveness, and global supply chain integration. This study addresses one of the most pressing issues, container dwell time, that has a direct impact on logistics cost, shipping turnaround, and overall Ease of Doing Business (EoDB).

From a policy perspective, this study supports India's aspirations outlined in the Maritime India Vision 2030, which emphasizes reducing dwell time to under 24 hours. Similarly, the Maritime Amrit Kaal Vision 2047 aims for world-class logistical performance and

globally competitive port infrastructure. This study offers evidence-based insights that can influence future policy formulations. From a port management viewpoint, reducing dwell time can improve terminal efficiency, increase throughput, and enhance port revenue. Port authorities, terminal operators and logistics service providers can use the findings to fine-tune their operational models and integrate technologies like IoT, AI, and blockchain for better real-time coordination.

The study is also crucial for trade and industry players, including exporters, importers, freight forwarders, and shipping lines. Long dwell times result in increased demurrage, delays in inventory delivery, and reduced predictability, affecting supply chain performance. These players can benefit from the study's recommendations for optimizing logistics planning. Finally, for the academic and research community, this study contributes to the literature in the domain of maritime logistics, port performance metrics, and trade facilitation. It offers a model that could be applied to similar developing economies with comparable port challenges. Overall, the study provides a multi-stakeholder value proposition by contributing to both practical and theoretical aspects of port logistics.

1.6 Scope of the Study

The research adopts an empirical analytical approach grounded in the use of secondary data. Empirical research is defined as the methodical investigation of observed and documented phenomena. In this context, the study relies only on secondary data sources such as official statistics published by the Indian Ports Association, reports from the Ministry of Ports, Shipping, NICDC Logistics Data Services and Waterways, and databases maintained by international organizations like UNCTAD and the World Bank. These sources provide quantifiable and time-bound information on container dwell time across major Indian ports. The use of secondary data is particularly appropriate for this study, as it allows for comprehensive trend analysis and benchmarking over multiple years. Furthermore, this approach enables the researcher to draw evidence-based conclusions about operational efficiency without the resource constraints and logistical complexities associated with primary data collection.

This study is primarily focused on analysing and improving container dwell time at Indian ports. The geographic scope is limited to selected major ports. These ports represent a mix of government and private operations and cover both eastern and western

coastlines, providing a comprehensive view of national port operations. The time frame for data analysis spans the past six years (2019–2024), allowing for the examination of trends before, during, and after the COVID-19 pandemic. It also enables assessment of the impact of recent digital and infrastructural initiatives.

The study specifically targets containerized cargo and excludes bulk, break-bulk, and liquid cargo due to differences in operational processes and dwell time dynamics. In terms of methodological limitations, the study relies primarily on secondary data sources due to access constraints and time considerations. However, extensive primary fieldwork is not part of the present scope. It is limited to descriptive statistical analysis, trend identification, and data interpretation based on reported figures.

1.6.1 Global and National Initiatives

Globally, countries have adopted multiple strategies to improve port performance. For example, ports in Singapore, Rotterdam, and Busan have achieved low dwell times through digital integration, 24x7 customs clearance, and highly automated terminal operations. The World Bank's Container Port Performance Index (CPPI) and Logistics Performance Index (LPI) serve as global benchmarks for comparative analysis.

According to the UNCTAD 2023 Review of Maritime Transport, efficient dwell time management reduces port congestion, improves vessel turnaround, and leads to sustainable cost savings. Also, trends such as the use of AI for predictive cargo handling, blockchain for trade documentation, and IoT for container tracking have significantly optimized operations.

At the national level, India has taken several initiatives to address port inefficiencies:

1. Port Community System (PCS 1x): A digital single-window interface launched by IPA to facilitate real-time exchange of data among stakeholders.
2. Sagarmala Project: Aimed at port-led development, modernization, and multimodal connectivity.
3. Direct Port Delivery (DPD): Enables importers to clear goods directly from ports, reducing storage time.

4. PM Gati Shakti: An integrated infrastructure plan focused on synchronized development across logistics, rail, road, and maritime.
5. Maritime India Vision 2030: Targets reducing port dwell time to less than 24 hours and aims to invest over ₹3 lakh crore in port infrastructure.
6. Maritime Amrit Kaal Vision 2047: A long-term strategy to transform India into a global maritime leader with sustainable and technologically advanced port ecosystems.

1.6.2 Delimitations of the Study

Despite these initiatives, implementation gaps remain. Digital systems are often fragmented, and customs operations are not uniformly efficient. This study seeks to evaluate the effectiveness of these initiatives with a specific lens on dwell time. Delimitations also include the exclusion of inland container depots (ICDs) and customs bonded warehouses from the primary analysis, though their roles may be discussed in the context of hinterland connectivity. The study's geographical scope is limited to India, though international best practices are referenced for comparative insights.

1.7 Limitations of the Study

While the research is structured to offer useful insights into container dwell time trends, certain limitations must be acknowledged:

1. Lack of primary data: The study does not include interviews with port officials, customs officers, or logistics stakeholders, which could provide qualitative context to the numerical analysis.
2. Reliance on available secondary data: There may be inconsistencies, gaps, or delays in how dwell time data is reported by different ports or terminals. The absence of a standardized reporting framework can affect the reliability of cross-port comparisons.
3. No predictive or optimization models: This study does not employ machine learning or statistical forecasting models, which could have potentially added predictive value to the analysis.
4. Limited control over external variables: Factors such as labor strikes, policy changes, or infrastructure upgrades during the studied period are beyond the scope of the analysis but may influence dwell time trends.

5. Focus on major ports only: The exclusion of minor ports or inland container depots limits the generalizability of findings to the entire Indian port network.

Despite these limitations, the study offers meaningful insights into historical performance and provides a data-grounded foundation for further applied research or policy reforms.

1.8 Organization of the Study

This study is divided into six continuous parts that go logically through the narrative, offering a methodical investigation of container stay time at Indian ports and realistic recommendations for improvement. Each chapter addresses a distinct aspect of the study, from conceptual grounding to empirical evaluation and policy guidance.

Chapter 1: Introduction provides the background and rationale of the study, defines the research problem, outlines the objectives and scope, and explains the significance of examining container dwell time in the Indian port sector.

Chapter 2: Review of Literature presents a detailed survey of theoretical and empirical studies relevant to port performance, container dwell time, and logistics efficiency. It identifies key research gaps and establishes the conceptual framework supporting this study.

Chapter 3: Research Methodology describes the research approach, including the design, data collection methods, and analytical tools employed. It ensures the validity and reliability of the research by justifying the selected methods.

Chapter 4: Data Analysis and Interpretation discusses the empirical findings derived from statistical and graphical analysis of container dwell time data across Indian ports. It interprets these results about the study objectives and identifies patterns and inefficiencies in port operations.

Chapter 5: Findings and Recommendations summarizes the key findings of the research and proposes practical recommendations aimed at improving container dwell time performance. The suggestions are targeted toward port authorities, terminal operators, and policymakers to enhance operational efficiency.

Chapter 6: Conclusion encapsulates the overall insights gained from the study, reinforces the contributions made to academic and practical fields, and outlines the limitations of

the research. It also identifies prospective areas for further exploration. This framework provides a logical flow and thorough coverage of the study topic.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Container dwell time, the total time a container remains in a port terminal from discharge to removal, has emerged as a crucial metric for evaluating port efficiency. As global trade volumes expand and supply chains grow increasingly complex, minimizing container dwell time has become imperative for cost-effective logistics, faster cargo clearance, and enhanced port competitiveness. Several researchers, such as Moini et al. (2020), Ewamer and Menyhárt (2022), Huynh (2010), and Dally et al. (2020) identify long dwell times as a key contributor to terminal congestion, higher logistics costs, and vessel delays. The UNCTAD Review of Maritime Transport (2023) emphasizes that improving cargo dwell time is essential for improving a country's Logistics Performance Index (LPI) score. Zaoudi et al. (2022) further support the impact of dwell time on container port capacity and productivity.

2.2 Concept of Container Dwell Time

Container dwell time is broadly defined as the duration between unloading a container from a ship and removing it from the port terminal. According to (Moini et al., 2012) “Container dwell time is the time elapsed from when a container is unloaded from a vessel until it leaves the port terminal by a truck or train”. (Ewamer & Menyhárt, 2022) describe it as “the length of time that an import container stays in the terminal yard before being picked up by the consignee”, emphasizing the importer's perspective. According to (Saini & Lerher, 2024) “Container dwell time reflects how efficiently port infrastructure, customs authorities, and cargo owners coordinate to move containers out of the terminal”. (Wardana et al., 2024) explain that dwell time is also an indicator of how sustainable and fluid port logistics are in a maritime economy. These definitions show that container dwell time is not only a technical metric but also a multidimensional indicator of supply chain coordination and port productivity.

2.3 Factors Influencing Dwell Time at Ports

Several studies have highlighted a variety of factors contributing to prolonged dwell time in port terminals, emphasizing both operational inefficiencies and infrastructural limitations. (Koley et al., 2016) emphasize that "manual checking of documents and delays in customs clearance continue to extend the time containers remain within port terminals". These administrative processes, while essential for ensuring regulatory

compliance, often become bottlenecks that slow down the flow of cargo through the port. The human dependency in handling documentation, compounded by outdated systems, results in delays that are difficult to mitigate without a significant overhaul of customs procedures. In addition to procedural inefficiencies, Soul & Mola (2010) points out that "the inability to streamline procedures between port authorities, customs, and freight forwarders results in prolonged cargo stays". This lack of coordination among the various stakeholders involved in port operations exacerbates the time containers spend at ports. A failure to align processes and communication between authorities and service providers creates delays that increase dwell time, underscoring the need for better integration of port operations. Without a holistic approach to streamline these procedures, ports risk continued inefficiencies that hinder their ability to meet global logistics demands.

Infrastructure-related issues are also crucial for understanding dwell time. These physical constraints significantly impact the efficiency of cargo handling operations. The limited availability of cranes to unload and transfer containers leads to congestion, while the high occupancy of yard space restricts the movement and turnaround of containers, creating a backlog that increases dwell time. Moreover, the absence of advanced technological systems compounds these challenges. (Machado & Brazil, n.d.) emphasizes that "a lack of real-time ICT systems limits the ability of ports to coordinate yard space allocation and dispatch efficiently". Without real-time data monitoring and automated systems, ports struggle to optimize operations, leading to inefficiencies in space management and the allocation of resources, which further prolong container dwell time. These findings collectively reinforce the idea that infrastructure shortcomings, policy inefficiencies, and the absence of modern digital systems significantly contribute to increased dwell time. To address these issues, ports must focus on modernizing their infrastructure, enhancing inter-agency coordination, and adopting digital solutions to streamline operations.

2.4 International Best Practices and Benchmarks

Global benchmarks for dwell time are exemplified by ports like Singapore, Rotterdam, and Shanghai. According to (Beuran et al., n.d.), "Singapore has managed to maintain an average dwell time of fewer than 2 days through port automation and community system integration". (Soul & Mola, 2010) notes that "the Kenya TradeNet system reduced Mombasa Port's average dwell time from 11.6 to 4.3 days within three years". (Nur et al., 2019) report that "dry port integration in Indonesia has helped reduce container

congestion in seaport terminals by redirecting cargo inland after initial clearance. (Budiyanto et al., 2023) found that "increasing the number of quay cranes and shifting to automated handling processes improved productivity by over 25% at Tanjung Priok Port". These international examples provide actionable insights into how operational, digital, and policy reforms can drastically improve dwell time performance.

2.5 Review of Studies on Indian Ports

Numerous studies have evaluated container dwell time in the Indian port context. According to (Koley et al., 2016) "The absence of electronic documentation and reliance on manual processes significantly prolongs dwell time, especially in older terminals such as Kolkata Port". (Saini & Lerher, 2024) emphasized that "ports with RFID-based truck monitoring and digitized gate entry systems reported lower mean dwell times by up to 18%". (Iyer & Nanyam, 2021) stated that "Indian ports ranked lower on terminal productivity metrics when compared to international benchmarks, largely due to fragmented customs and poor hinterland linkages". These studies collectively highlight systemic issues affecting port operations in India, despite various modernization efforts.

2.6 Conceptual Framework

As stated by (Koley et al., 2016) "Container yard layout and gate automation have a measurable impact on container dwell duration". (Saini & Lerher, 2024) highlight that "Real-time visibility of containers in the yard, enabled by RFID and IoT systems, can improve truck turnaround and reduce dwell time". According to (Moini et al., 2012) "Delays in customs verification and documentation clearance contribute to over 30% of total dwell time in high-volume ports". Thus, infrastructure, process, and technology form the critical triad influencing container dwell time at Indian ports.

2.7 Empirical Review

The empirical literature on dwell time spans multiple geographies and methodologies. (Moini et al., 2012) found that "electronic data interchange and pre-arrival documentation reduced container dwell time by 25% across West Coast U.S. ports". (Ewamer & Menyhárt, 2022) reported that "inconsistent communication among stakeholders resulted in redundant documentation checks, leading to time wastage". (Budiyanto et al., 2023)

observed that “ports with synchronized gate-in and gate-out processes showed a 30% reduction in average container dwell time”. (Iyer & Nanyam, 2021) concluded that “a strong correlation exists between crane density and dwell time across Indian ports, suggesting infrastructure gaps are still persistent”. These findings reinforce the need for systemic reforms that combine technology, infrastructure, and stakeholder alignment.

2.8 Critique of Existing Literature

Despite the progress in container dwell time research, several limitations remain. According to Saini and Lerher (2021), “most Indian studies focus narrowly on container handling without considering external logistics chains such as rail or inland depots”. Park et al. (2021) point out that “current predictive models often omit real-time feedback loops from the port community system, which restricts dynamic decision-making”. This critique reveals the fragmented and often siloed approach taken in most studies on dwell time, suggesting an opportunity for more integrative, longitudinal, and technology-driven research.

2.9 Research Gaps Identified

Despite the growing literature on container dwell time, several notable research gaps persist, particularly in the context of Indian ports. First, there is a scarcity of longitudinal studies that last more than a few years. This study addresses this by analysing six years of port performance. Second, while many studies explore individual causes of dwell time, very few investigate interactions among multiple variables. For example, (Saini & Lerher, 2024), highlight that “despite improvements in gate automation, delays in customs clearance continue to prolong dwell time, indicating a lack of coordinated process optimization”. This interplay between infrastructure and process efficiency remains underexplored.

Third, there has been little empirical research on new technologies in the Indian setting. (Nur et al., 2019) note that “although the Indonesian government has promoted digital documentation, the implementation of blockchain or AI-based clearance paths has been slow and largely unmeasured”. Similar gaps exist in India, despite references to the Maritime India Vision 2030. Fourth, coordination methods between stakeholders (customs, port authorities, and transporters) are understudied. (Myriam Gaete et al., 2017) stress that “existing models seldom integrate decision-support frameworks that consider

the dynamic interactions between port-side and inland logistics actors". Such integration is critical for Indian ports undergoing multimodal expansion under projects like Bharatmala. Fifth, there is limited literature on how cargo type variation and seasonality impact dwell time. According to (Aminatou et al., 2018), "few studies disaggregate container dwell times by commodity type, yet perishables and electronics show distinct dwell behaviours". Understanding this heterogeneity is crucial for designing flexible yard and customs strategies. Finally, real-time data utilization and prediction technologies are yet immature in the existing literature. (Park et al., n.d.)argue that "the absence of real-time dwell time forecasting systems limits proactive yard planning and resource allocation". Most Indian ports still rely on historical reports rather than dynamic decision-making systems. Collectively, these gaps call for more integrative, tech-aware, and longitudinal studies. Addressing them will better inform operational policy and help Indian ports align with international performance benchmarks.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Design

For this study, a descriptive and analytical research design was chosen. The descriptive component helps in identifying and understanding the current state of container dwell time across major Indian ports, while the analytical part focuses on assessing the reasons behind prolonged dwell time and suggesting improvements. The study aims to describe operational patterns and evaluate influencing factors such as infrastructure limitations, procedural inefficiencies, and digital system gaps. This dual emphasis enables a thorough comprehension of the issue. A cross-sectional study design is used; this design is well-suited for identifying trends, comparing port performance, and highlighting inefficiencies. The ports selected are among the major Indian ports listed by the Indian Ports Association, ensuring relevance and generalizability.

3.2 Sources of Data

This study primarily depends on secondary data to conduct a detailed analysis of container dwell time across some Indian ports. Secondary data sources offer a cost-effective and reliable foundation for understanding historical and current port operations. These were gathered from reliable institutional sources including the Ministry of Ports, Shipping, and Waterways, the Indian Ports Association (IPA), and National Logistics Data Services (NLDS) reports. Additionally, port trust websites for key ports like Jawaharlal Nehru Port Authority (JNPA), Chennai Port Trust, and Mundra Port provide port-specific performance data essential for comparative analysis. To supplement national data, international benchmarking is performed using statistics and performance reports from globally recognized organizations such as the United Nations Conference on Trade and Development (UNCTAD), the World Bank, and the World Customs Organization (WCO). These sources provide valuable insights into global dwell time norms, enabling an evaluation of Indian port performance against international standards.

Furthermore, a review of academic journal articles, white papers, and industry case studies, such as those by Koley et al. (2020), Vasan and Chavan (2021), and Machado Junior (2021), adds theoretical depth and context. These materials help interpret the data in light of previously identified inefficiencies, bottlenecks, and digital transformation challenges. All secondary data are carefully examined for source reliability, publication recency, and relevance to ensure consistency and analytical integrity. The cross-

verification of multiple sources supports a robust analysis while mitigating the risks of biased or outdated information.

3.3 Data Collection Methods

The data collection process for this research is primarily centered around the systematic retrieval and analysis of secondary data, given the study's emphasis on historical trends in container dwell time across Indian ports. The data collection methods are designed to ensure accuracy, relevance, and comparability of information, with a particular focus on major ports under the Indian government’s jurisdiction. The core data sources include published government reports, port authority dashboards, annual performance reviews, and logistics data repositories such as the Indian Ports Association (IPA), Ministry of Ports, Shipping and Waterways, and National Logistics Portal (Marine). Each of these institutions regularly publishes port performance indicators, including average container dwell time, berth productivity, yard occupancy rates, customs clearance durations, and container handling statistics.

Additionally, port-specific websites like those of JNPA, Chennai Port, offer terminal-level operational statistics and infrastructure updates that supplement broader national data. Global benchmarking data from organizations like the World Bank’s Logistics Performance Index (LPI), UNCTAD Port Performance Indicators, and WCO customs modernization reports are used to place Indian port performance in a global context. To find trends and abnormalities, all gathered data is categorized and arranged using Microsoft Excel and visualization tools. The integrity and robustness of the research findings are guaranteed by this all-encompassing strategy.

3.4 Tools and Techniques for Data Analysis

Both quantitative and qualitative analysis approaches are used in the study. For numerical data, Microsoft Excel will be used for creating pivot tables, bar graphs, and trend lines to show how dwell time varies across ports and years. In RStudio, correlation analysis may be used to find connections between dwell time and import-export volume distribution.

3.5 Limitations of the Methodology

While this research is designed to be as comprehensive as possible, certain limitations must be acknowledged. First, the reliance on secondary data means the study is limited by the accuracy, completeness, and timeliness of government and port authority reports. Some data might be outdated or inconsistent across ports. Additionally, while Excel and thematic analysis provide useful insights, more advanced tools (e.g., SPSS) were not used due to the researcher's limited familiarity and time availability. This may slightly limit the depth of statistical inferences. The practical nature of the methodology is aligned with research expectations and provides actionable insights for improving port operations.

3.6 Ethical Considerations

This research adheres to standard academic and ethical guidelines. All secondary data used are from publicly available and credible sources such as government databases, international organizations, and peer-reviewed journals. To prevent plagiarism, proper citation in APA format is maintained. The research avoids any conflict of interest and maintains neutrality in analysis and interpretation. It also complies with the ethical standards set by the academic institution (IMU Chennai), and no data manipulation or misrepresentation is permitted. All data collected will be securely stored and used solely for this academic research.

CHAPTER 4

DATA ANALYSIS

4.1. Overview of Data Collected

The data used in this study were collected from secondary sources, which include NICDC Logistics Data services. The consolidated dataset includes port-wise and year-wise container dwell time values, spanning the period 2019 to 2024, covering major ports such as JNPA, Chennai Port, Kolkata Port, Visakhapatnam Port etc.

4.2 Trends in Container Dwell Time at Major Indian Ports

4.2.1 Port-wise Comparative Analysis

Port-wise analysis indicates considerable variation in container dwell time performance. For instance, JNPA consistently recorded the lowest average dwell time, owing to superior yard automation and faster customs processing. In contrast, Kolkata Port reported higher dwell times, attributed to procedural delays and lower cargo handling capacity. Chennai and Visakhapatnam Ports showed moderate performance but with noticeable year-to-year fluctuations. These differences highlight disparities in infrastructure and process efficiency.

4.2.2 Year-wise Trend Analysis

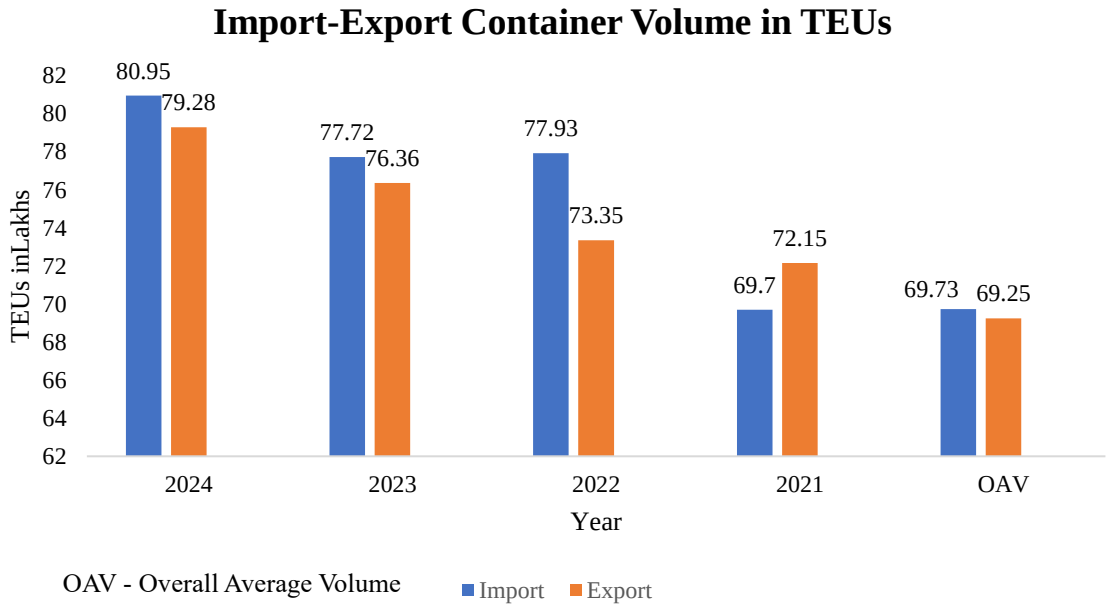
The year-wise trend analysis reveals a general downward trend in dwell time across most ports, especially between 2019 and 2021, likely due to the phased implementation of digitization initiatives such as ICEGATE and e-Sanchit. However, a temporary spike in dwell time was noted in 2020, which could be attributed to pandemic-induced disruptions. The data suggest an overall positive trend toward efficiency, although the rate of improvement varies by port.

Dwell Time of Various Indian Ports from 2019 to 2024

Ports	Dwell Time											
	2019		2020		2021		2022		2023		2024	
	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp
JNPA	23.45	66.3	28.2	71.2	21.2	71.2	21.8	74.5	21	70.9	23.1	75.2
Mundra	28.2	99.9	34.4	119.8	25.85	126.5	25.7	121.8	34.1	101.7	27.3	110
Pipavav	28.2	99.9	34.4	119.8	25.85	126.5	43.5	124.2	62.2	99	55.5	113.6
Kandla	28.2	99.9	42.9	131.7	54.3	124.3	52.2	115.3	33.7	91.5	36.8	85.3
Hazira	28.2	99.9	37.3	111.9	54.3	124.3	26.8	120.4	37.4	107.9	21.5	120.2
Chennai	36.7	77	48.5	92.5	51.3	92.2	40.9	94.9	42.2	84.5	46.6	92.9
Kochi	66.8	67.4	67.2	95.8	40.6	96.1	37.8	91	43.2	77.7	38.6	98.6
Kattupalli	54.26	99.4	88.99	114.6	62.1	99.3	50.3	89.5	49.5	85.2	60.7	100.5
Tuticorin	21.9	56.3	22.6	76.2	22.35	61.8	21.2	65.9	20.9	53.8	28.1	64.6
Ennore			72.2	90.8	52.4	97.9	41	103	40.1	94.4	51.7	105.6
New Mangalore	149.9	134.18	98.9	141.46	90.5	128.8	83.4	95.2	75.5	84.7	51.7	66.4
Visakhapatnam	45.3	71.9	56.5	100.3	57.7	103.8	66	87.7	63	83.7	55.6	92.7
Kolkata	34.7	106.5	46.4	121.5	32.7	134.4	34.3	114	35.2	118.5	43.8	126
Haldia	95.3	110.3	121.1	118.4	91.3	136.3	84.7	124.4	69	121.4	73.5	142.1

Source: NICDC Logistics Data Services

TABLE 1 IMPORT AND EXPORT DWELL TIME OF VARIOUS PORTS FROM 2019 TO 2024



Source: NICDC Logistics Data Services

FIGURE 1 IMPORT-EXPORT CONTAINER VOLUME IN TEUS

4.3 Forecasting Dwell Time Using Linear Regression in R

To support future planning and policy recommendations, dwell time forecasts were generated for the years 2025 to 2029 across major Indian ports. The forecasting was conducted using R Studio. The analysis used a linear regression model based on the least squares method. This approach models dwell time as a function of time for each port and direction, import and export, separately. The historical dwell time data from 2019 to 2024 served as the foundation for this predictive modelling. The data was first cleaned and reshaped into a long format using R packages like tidyr, dplyr, and purrr, after which regression models were fit for each Port-Direction pair. The regression models were then extended to predict dwell times for the years 2025 through 2029. Forecast outputs were saved graphically as individual port plots. In addition to forecasting, a correlation analysis was also performed between import/export volume distribution and corresponding dwell times. This was intended to explore the possible relationship between container traffic and the time spent at port terminals, potentially identifying congestion patterns or operational inefficiencies.

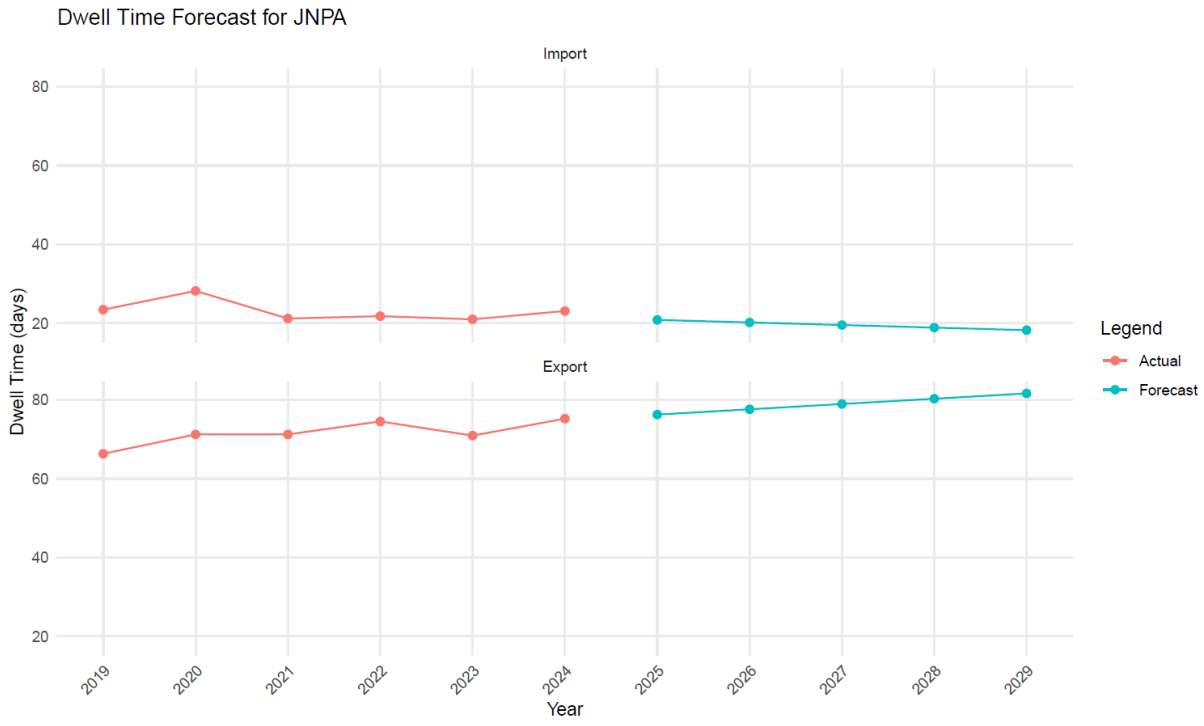


FIGURE 2 DWELL TIME FORECAST FOR JNPA FROM 2019 TO 2029

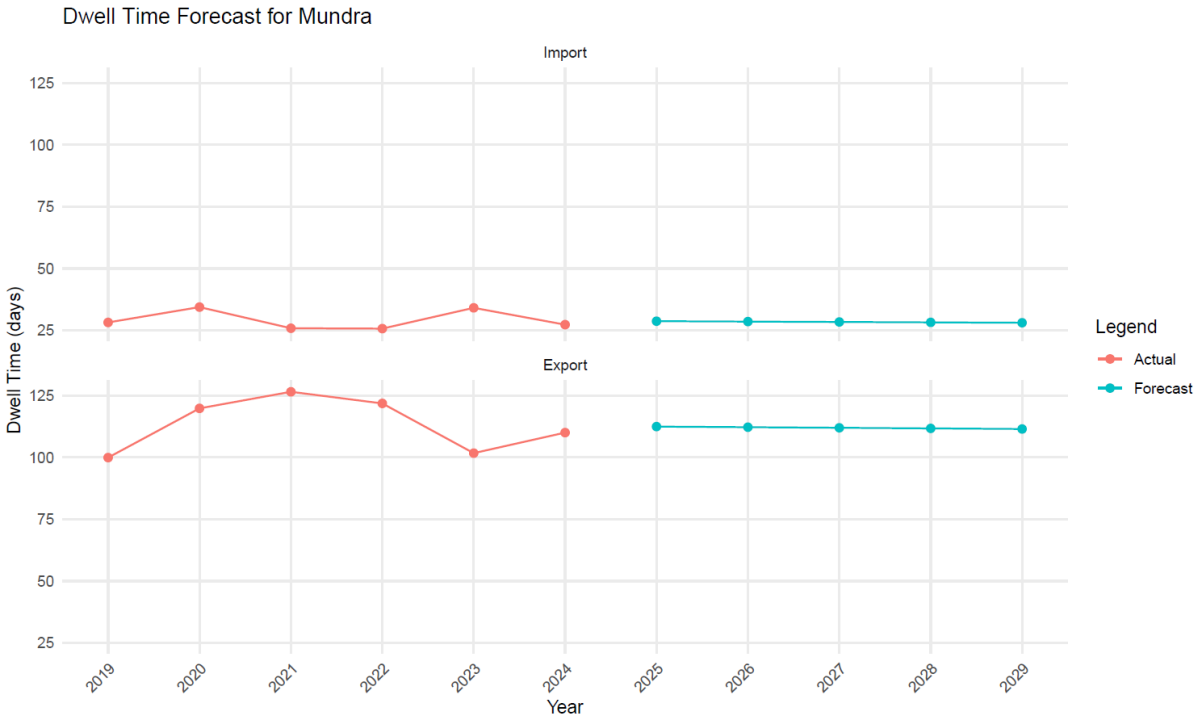


FIGURE 3 DWELL TIME FORECAST FOR MUNDRA FROM 2019 TO 2029

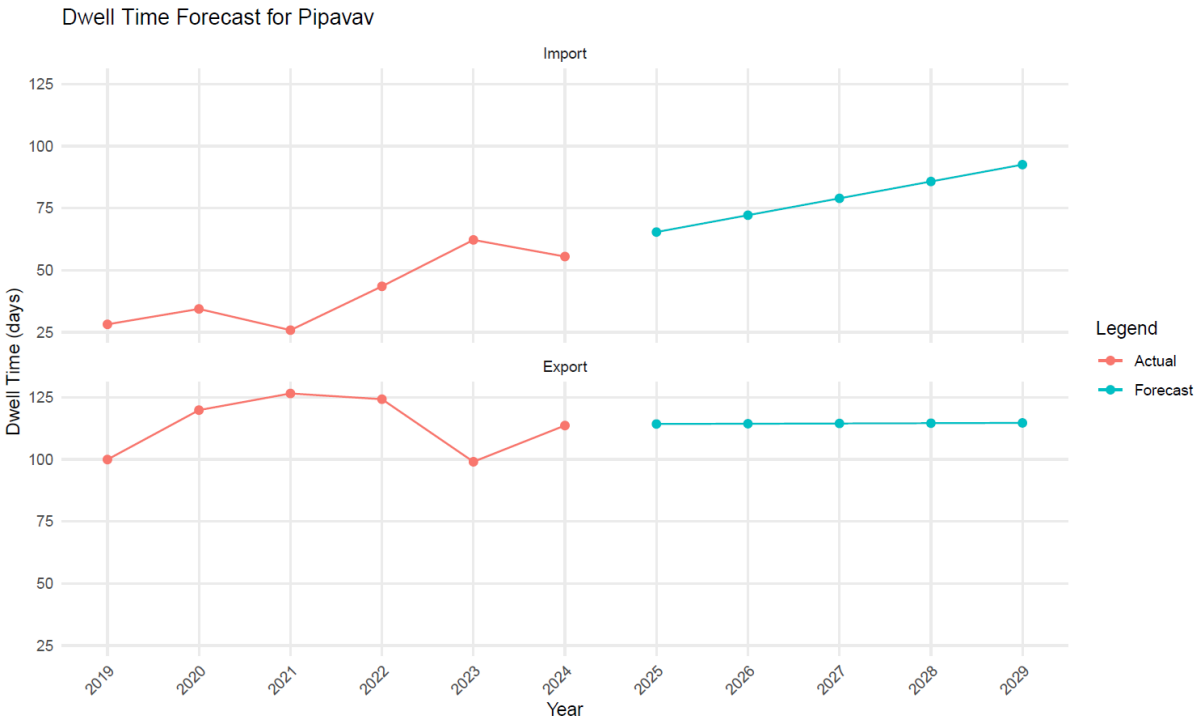


FIGURE 4 DWELL TIME FORECAST FOR PIPAVAV FROM 2019 TO 2029

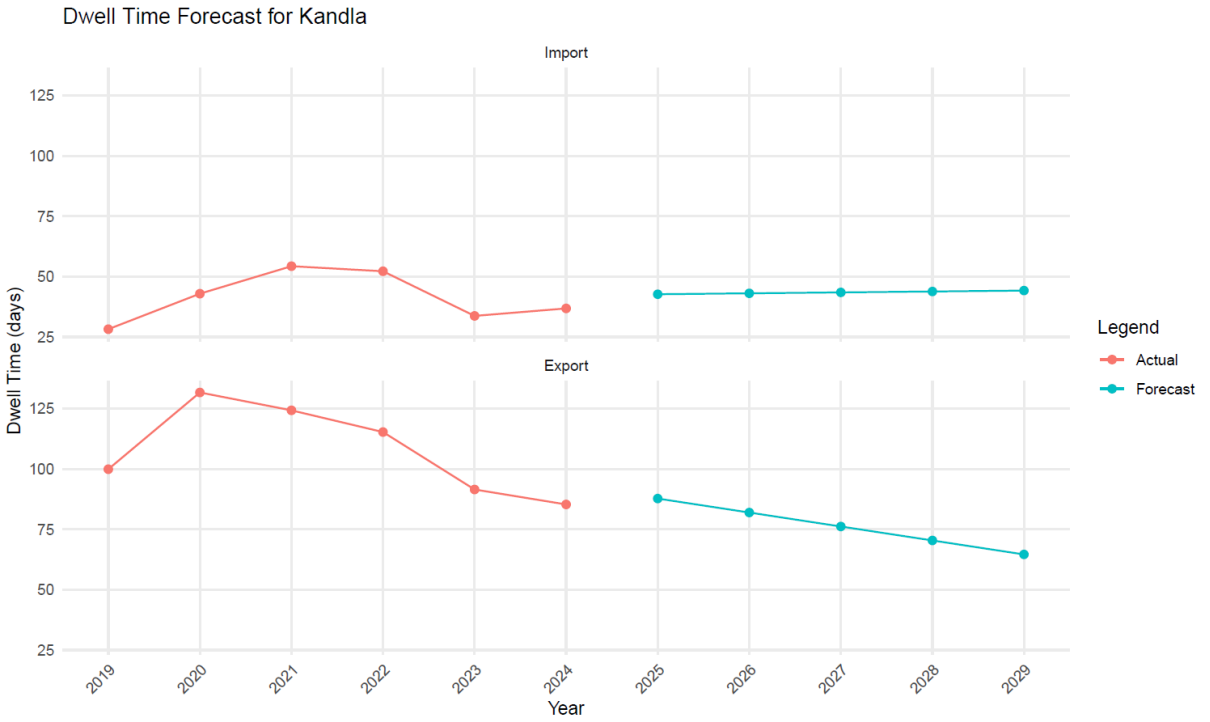


FIGURE 5 DWELL TIME FORECAST FOR KANDLA FROM 2019 TO 2029

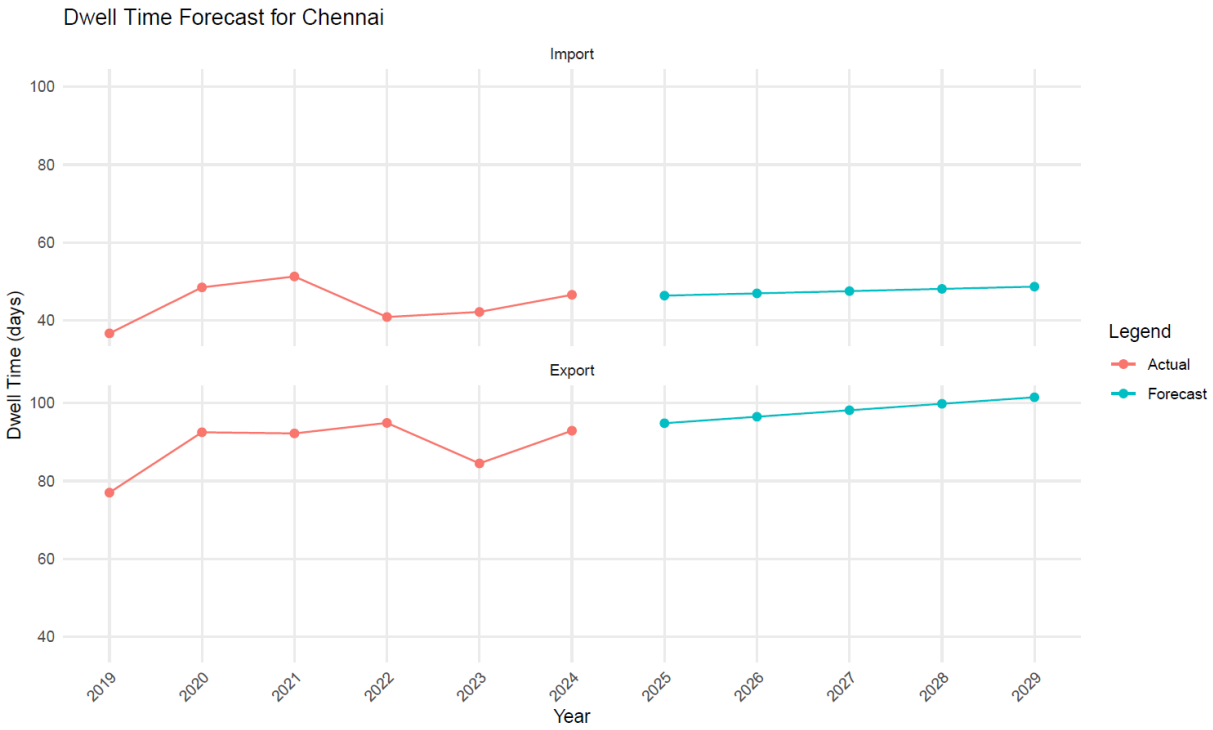


FIGURE 6 DWELL TIME FORECAST FOR CHENNAI FROM 2019 TO 2029

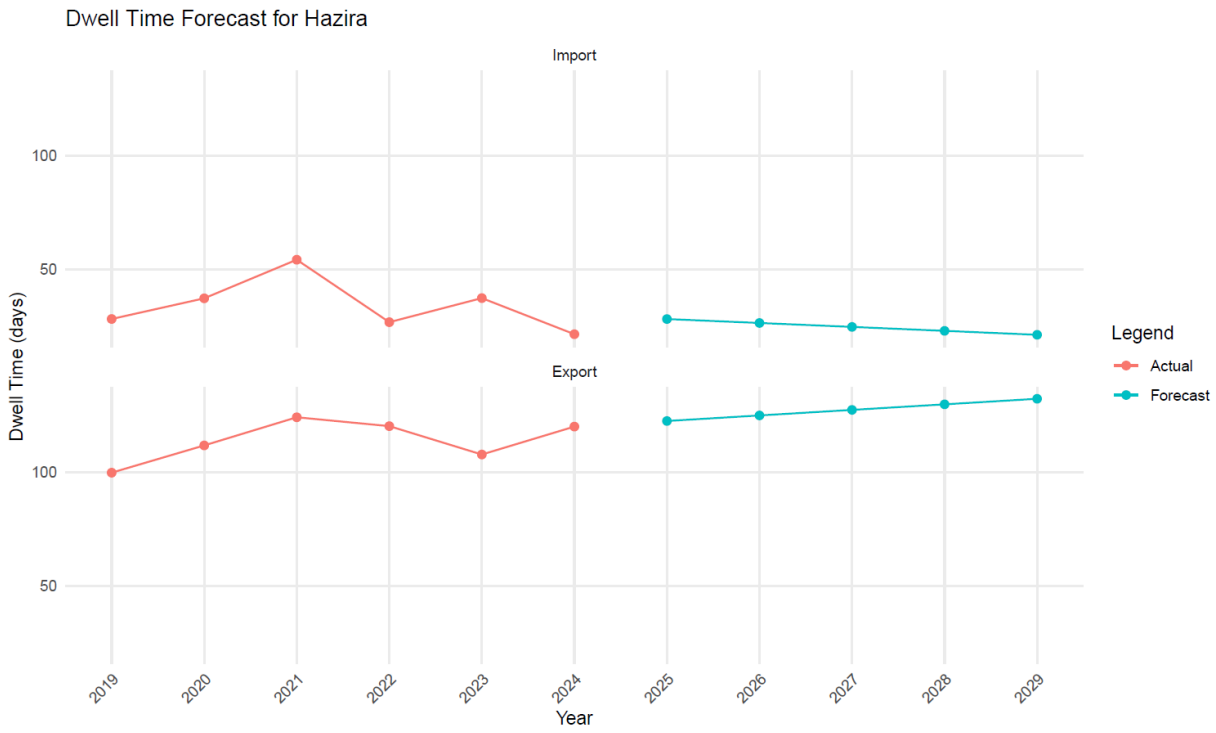


FIGURE 7 DWELL TIME FORECAST FOR HAZIRA FROM 2019 TO 2029

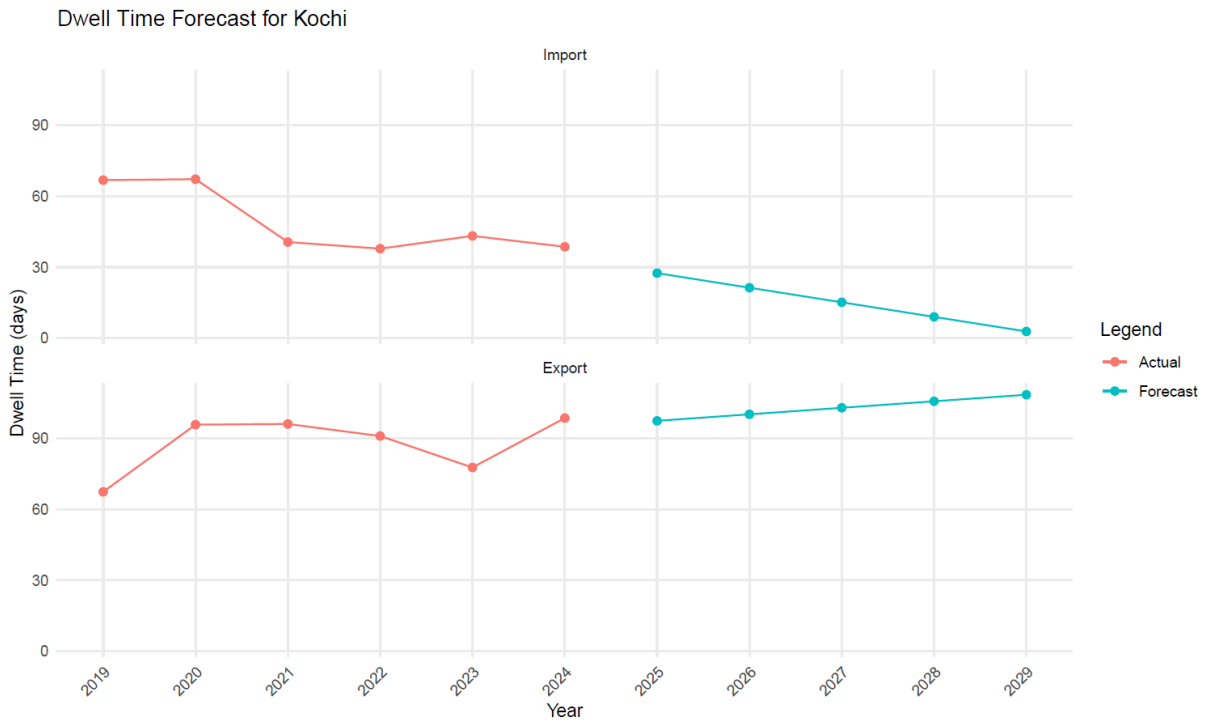


FIGURE 8 DWELL TIME FORECAST FOR KOCHI FROM 2019 TO 2029

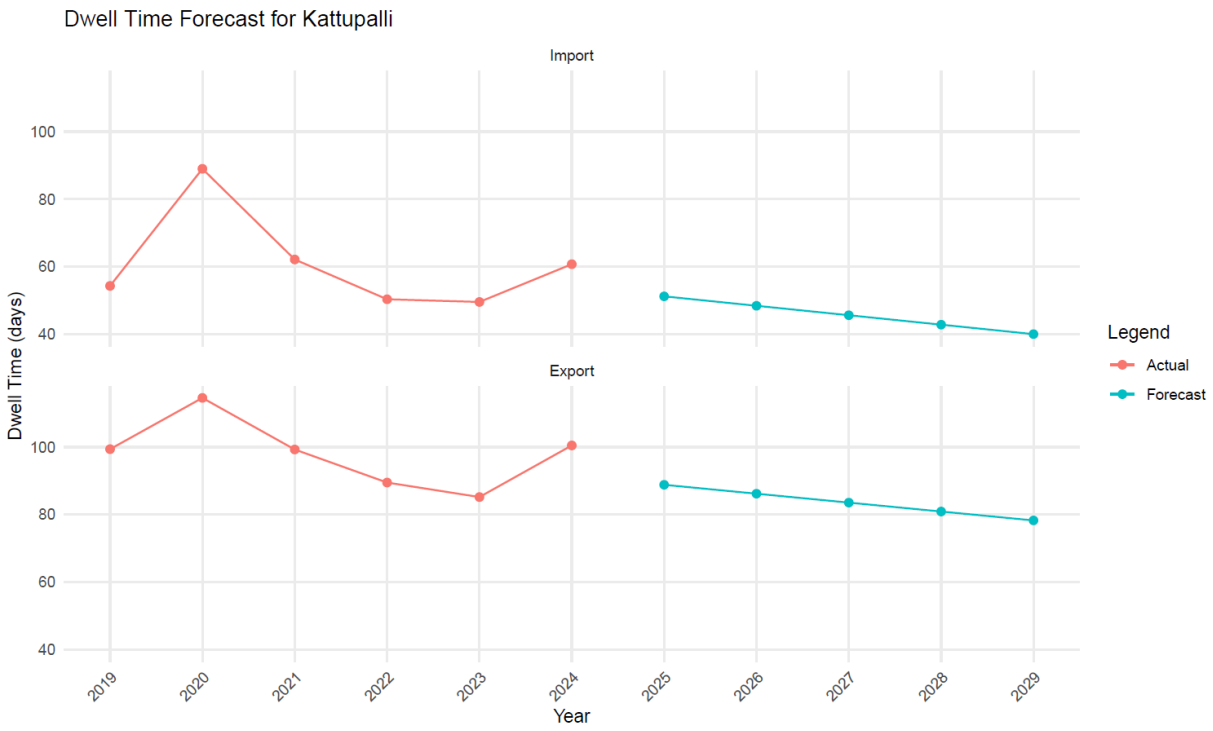


FIGURE 9 DWELL TIME FORECAST FOR KATTUPALLI FROM 2019 TO 2029

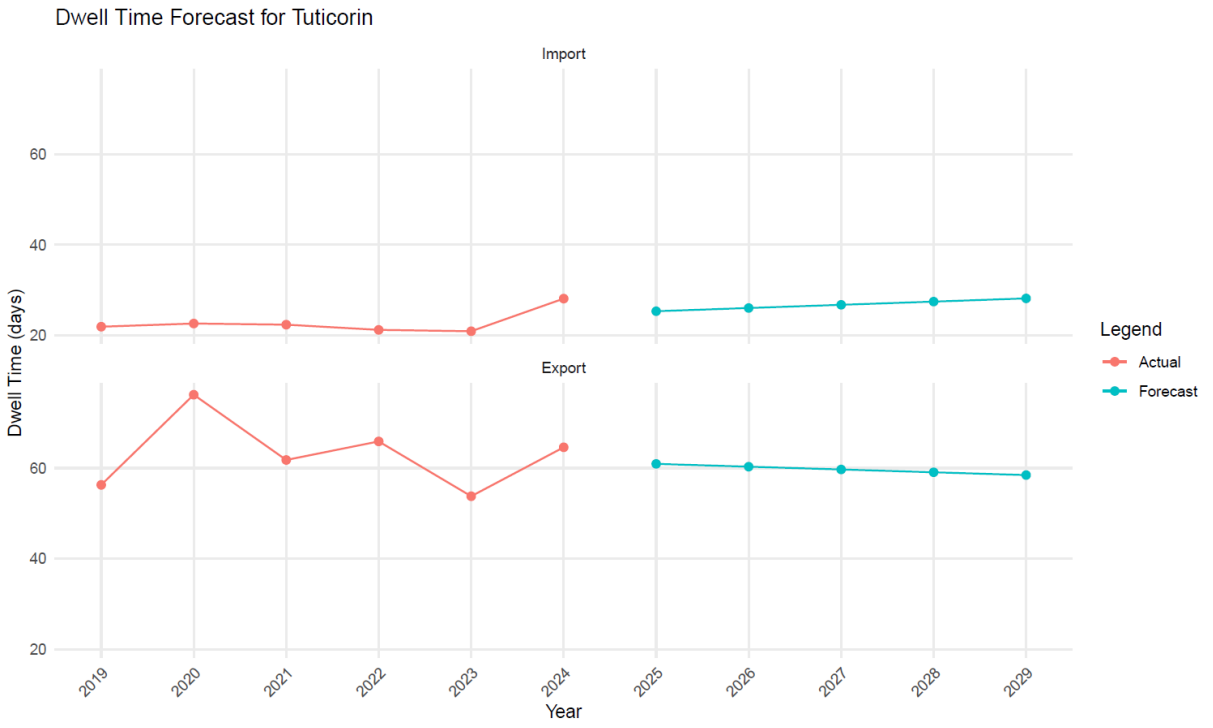


FIGURE 10 DWELL TIME FORECAST FOR TUTICORIN FROM 2019 TO 2029

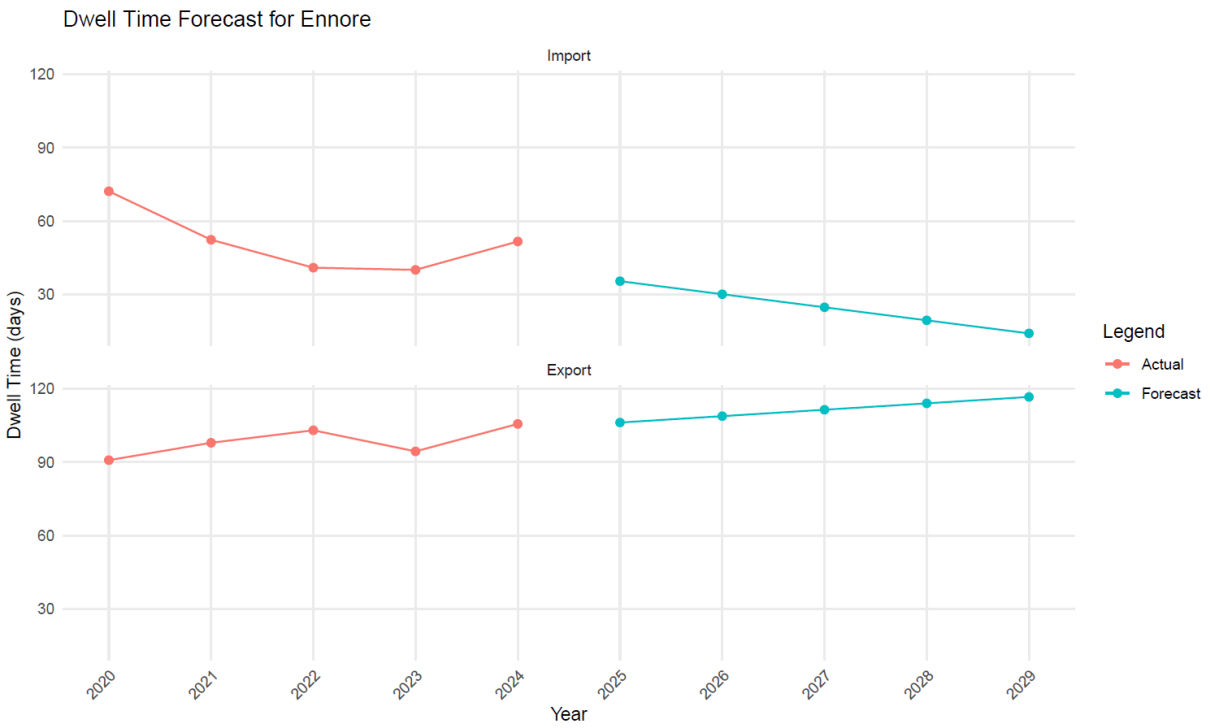


FIGURE 11 DWELL TIME FORECAST FOR ENNORE FROM 2019 TO 2029

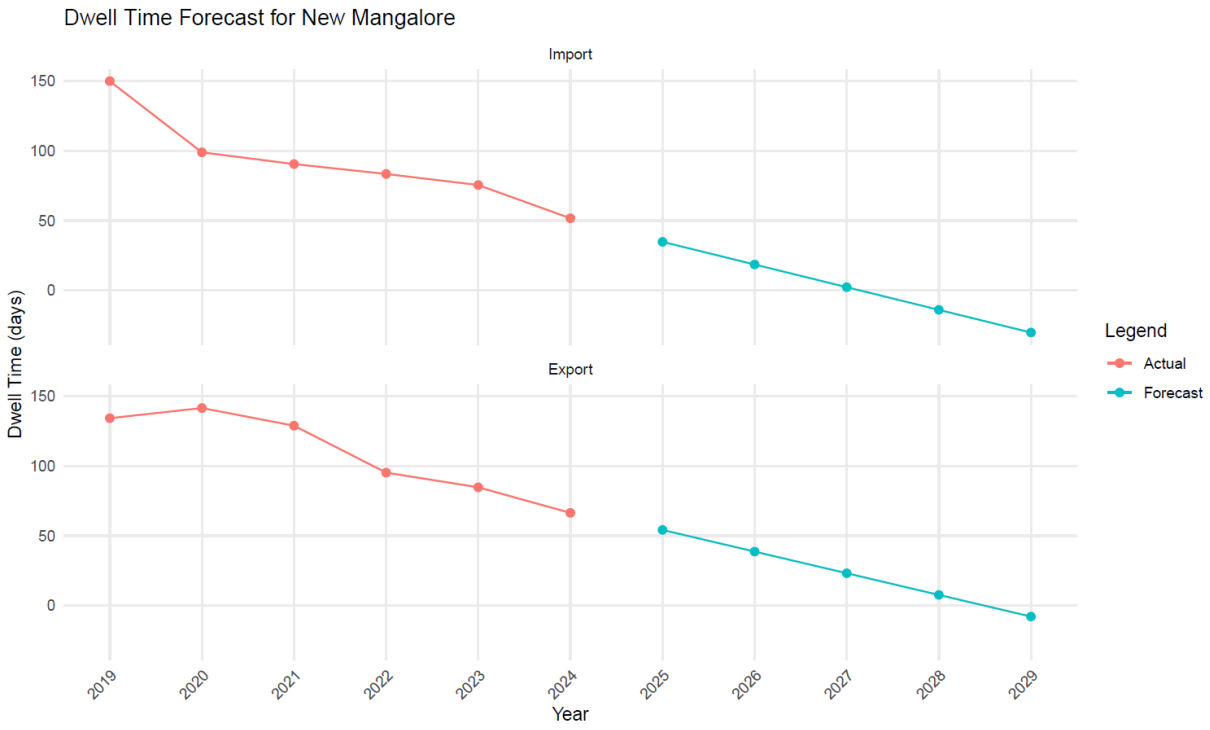


FIGURE 12 DWELL TIME FORECAST FOR NEW MANGALORE FROM 2019 TO 2029

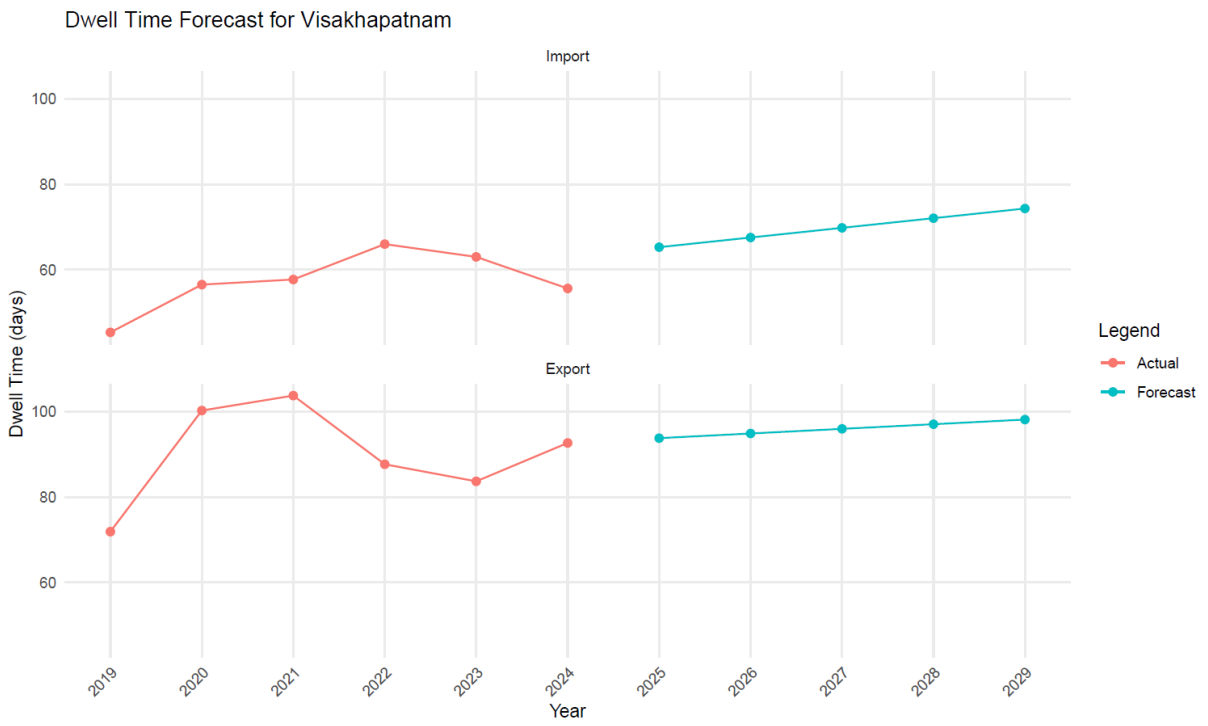


FIGURE 13 DWELL TIME FORECAST FOR VISAKHAPATNAM FROM 2019 TO 2029

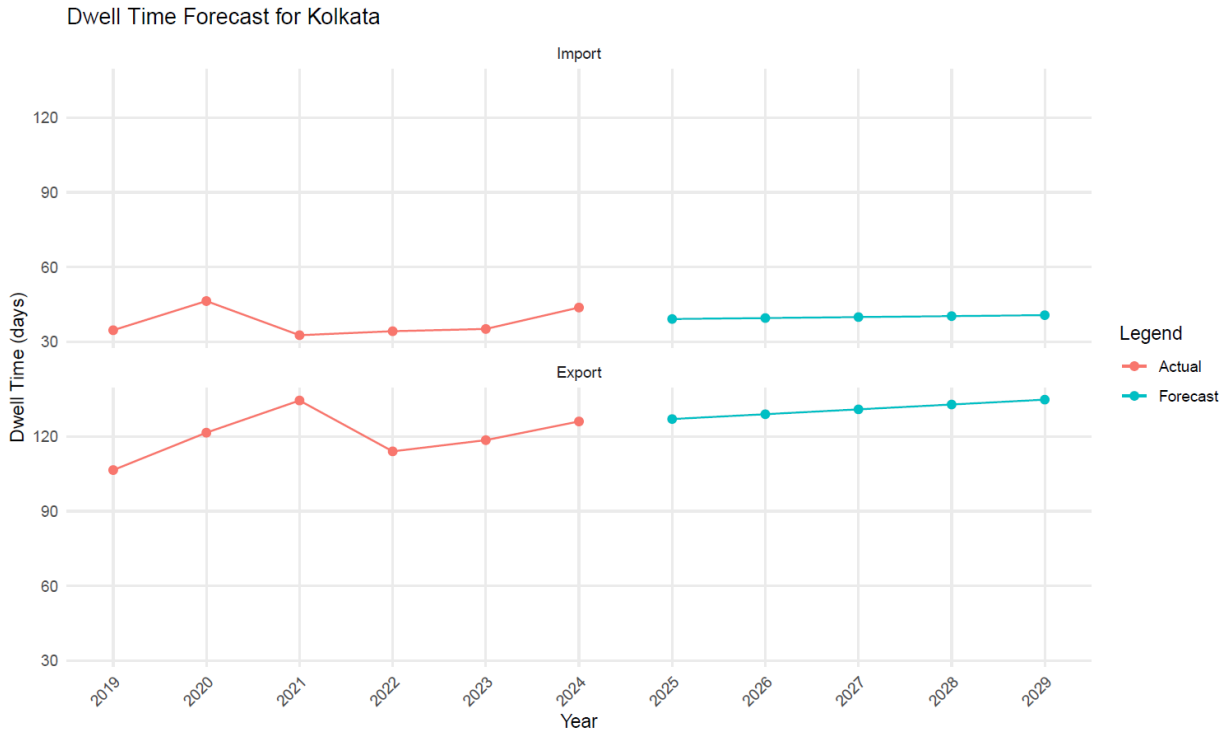


FIGURE 14 DWELL TIME FORECAST FOR KOLKATA FROM 2019 TO 2029

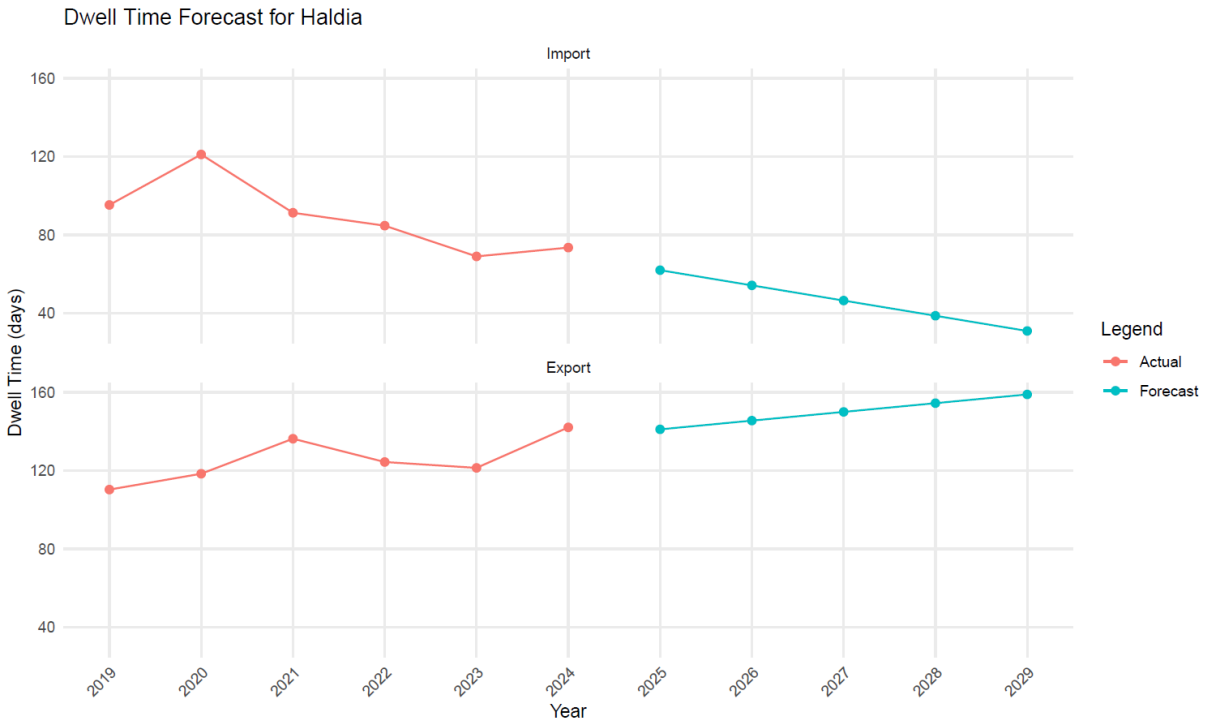


FIGURE 15 DWELL TIME FORECAST FOR HALDIA FROM 2019 TO 2029

The analysis of container dwell time data from 2019 to 2024 across various Indian ports presents a varied picture of performance on both the import and export fronts. For import dwell time, ports such as Jawaharlal Nehru Port Authority (JNPA), Mundra, and Chennai show a generally declining or stable trend over the six years. These ports appear to have benefited from operational improvements, digitization of customs clearance processes, and infrastructure upgrades. On the other hand, ports like Kochi and New Mangalore consistently exhibit higher import dwell times throughout the years, suggesting ongoing structural or procedural inefficiencies. Ports such as Hazira and Pipavav demonstrate relatively low and stable import dwell times, indicating streamlined operations and possibly more effective coordination with customs and transport systems.

Export dwell time trends show a different pattern. At most ports, export dwell times are consistently higher than import dwell times, with ports like Kolkata, Haldia, and Visakhapatnam recording export dwell times exceeding 100 hours in several years. This reveals a lag in outbound logistics efficiency and highlights issues such as delays in cargo aggregation, limited container availability, and less synchronized coordination with shipping lines. In contrast, ports like JNPA and Mundra, despite handling large volumes,

have managed to maintain relatively lower and more consistent export dwell times, reflecting the effectiveness of private terminal operations, real-time monitoring systems, and integrated freight corridors.

One noticeable pattern is that several underutilized ports, such as Ennore and New Mangalore, continue to report high dwell times for both imports and exports, indicating that inefficiencies are not necessarily linked to traffic volume. These observations underscore the importance of not only enhancing port infrastructure but also ensuring efficient inter-agency coordination, digital systems integration, and improved logistics connectivity. While some ports have clearly progressed in reducing dwell time through targeted interventions, others still face systemic challenges that hinder performance.

The forecasted container dwell time trends from 2025 to 2029 for 14 various Indian ports reveal important initial insights into the direction of port performance in the coming years. For import dwell times, ports like JNPA, Mundra, and Chennai are expected to show a steady or slightly declining trend, indicating continued gains from digitalization, infrastructure enhancement, and process streamlining. These projections reflect the positive impact of policy initiatives such as Maritime India Vision 2030 and the PM Gati Shakti program, which focus on multimodal connectivity and automation. In contrast, export dwell times at several ports, particularly Kolkata, Haldia, Visakhapatnam, and Pipavav, are forecasted to remain high or even increase slightly, suggesting potential challenges in cargo scheduling, vessel coordination, and terminal resource utilization. Underutilized ports like Ennore and New Mangalore are projected to continue exhibiting higher dwell times, pointing to structural inefficiencies unrelated to volume. Meanwhile, high-traffic ports like JNPA and Mundra are expected to maintain relatively stable export dwell times despite capacity pressure, which may be attributed to better operational planning and infrastructure resilience. These projections provide a directional understanding of where strategic reforms may be required and serve as the basis for further discussion in the subsequent chapter.

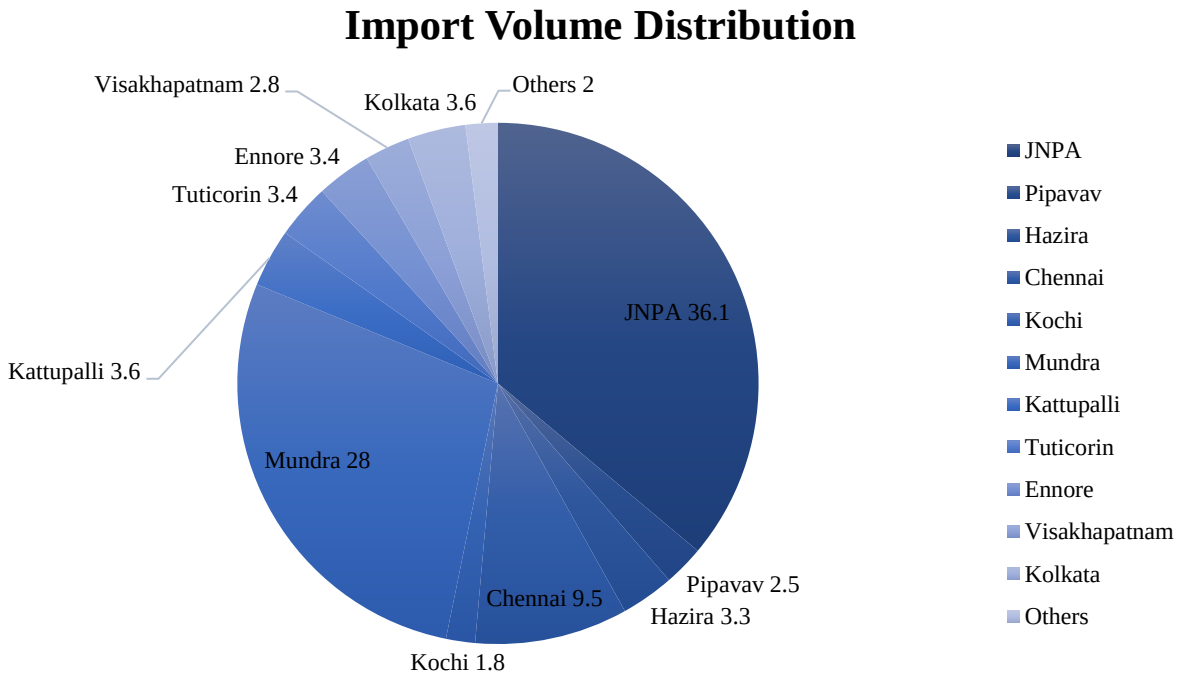
4.4 Correlation Between Container Volume Distribution and Dwell Time

Container Volume Distribution and Dwell Time of 2024

Ports	Import Volume	Import Dwell Time	Export Volume	Export Dwell Time
JNPA	36.1	23.1	36.1	75.2
Pipavav	2.5	55.5	1.3	113.6
Hazira	3.3	21.5	3	120.2
Chennai	9.5	46.6	8.3	92.9
Kochi	1.8	38.6	2.3	98.6
Mundra	28	27.3	34.2	110
Kattupalli	3.6	60.7	4.1	100.5
Tuticorin	3.4	28.1	3.4	64.6
Ennore	3.4	51.7	3.5	105.6
Visakhapatnam	2.8	55.6	3	92.7
Kolkata	3.6	43.8	3.6	126
Others	2	54	1.7	97.9

Source: NICDC Logistics Data Services

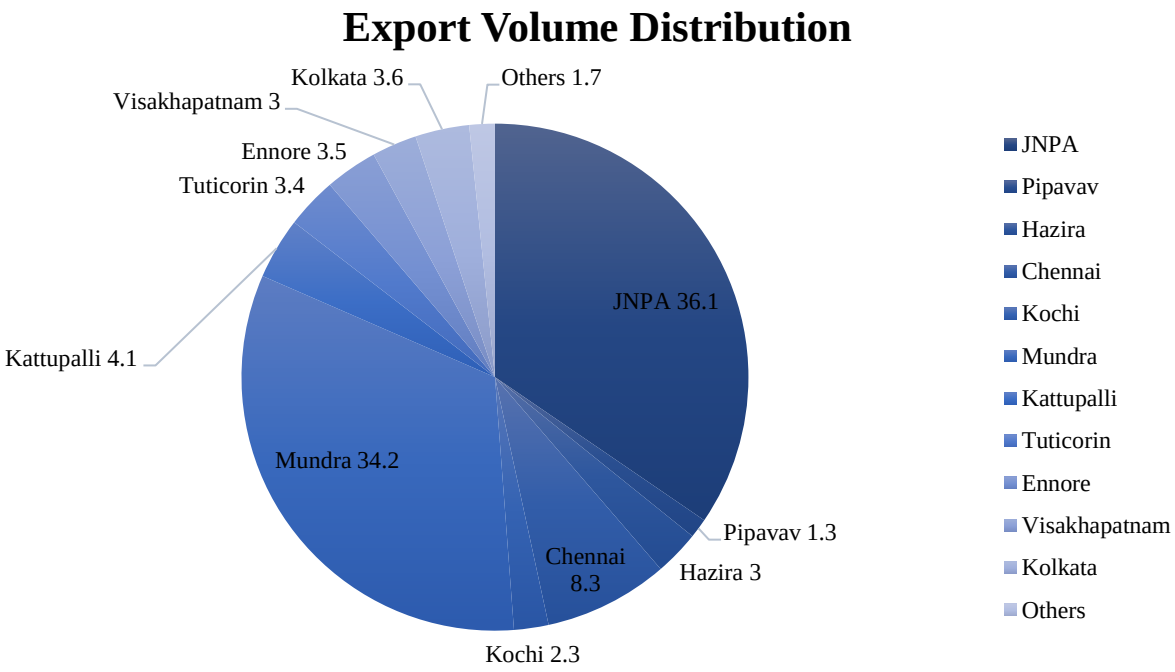
TABLE 2 CONTAINER VOLUME DISTRIBUTION AND DWELL TIME OF 2024



Source: NLDS Annual Report 2024

FIGURE 16 IMPORT VOLUME DISTRIBUTION FOR 2024

This pie chart shows the Import Volume Distribution across various Indian ports. JNPA leads with the highest share at 36.1%, followed by Mundra (28%) and Chennai (9.5%). Smaller contributions come from ports like Pipavav, Hazira, and Kochi. Ports like Kolkata, Kattupalli, and Visakhapatnam have nearly equal, smaller shares around 2.8–3.6%.



Source: NLDS Annual Report 2024

FIGURE 17 EXPORT VOLUME DISTRIBUTION FOR 2024

This pie chart illustrates the Export Volume Distribution across Indian ports. JNPA (36.1%) and Mundra (34.2%) lead the export share. Ports such as Chennai (8.3%) and Kattupalli (4.1%) contribute moderately. Smaller shares come from ports like Kochi, Hazira, and Pipavav.

Correlation Plot Of Volume Distribution And Dwell Time

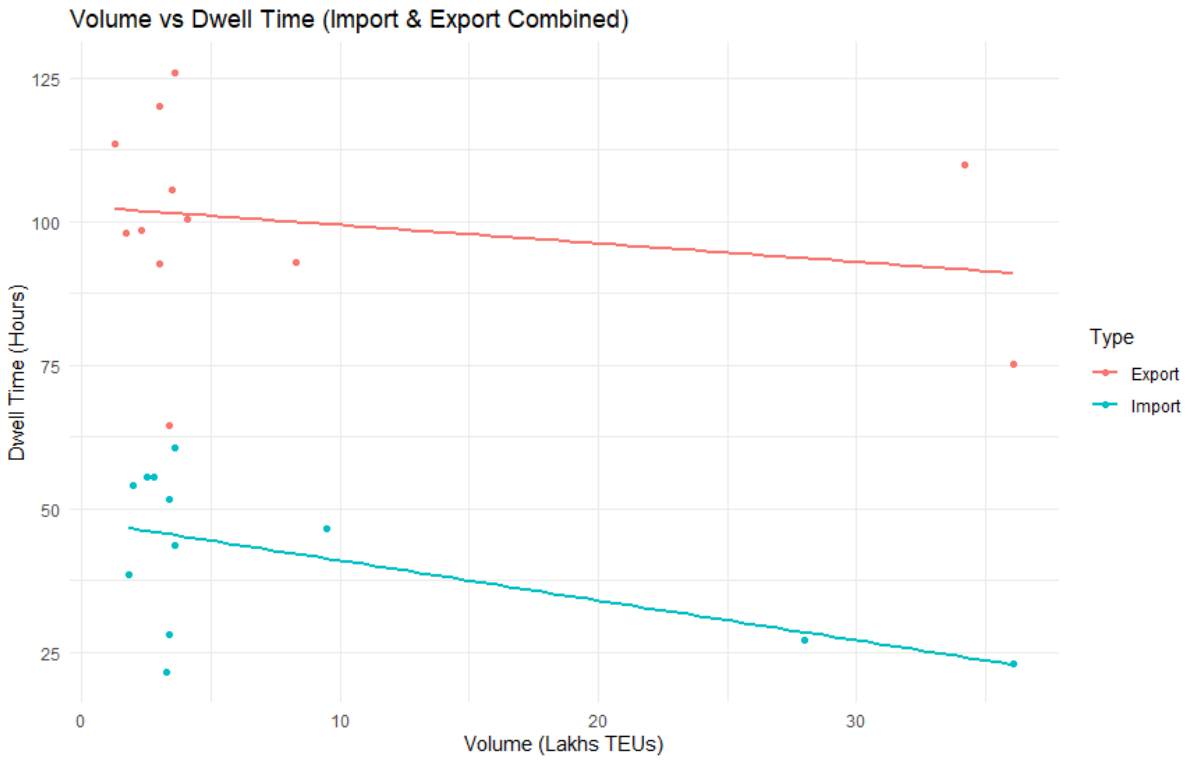


FIGURE 18 CORRELATION PLOT OF VOLUME DISTRIBUTION AND DWELL TIME OF 2024

The chart titled "Volume vs Dwell Time (Import & Export Combined)" presents a scatter plot with trend lines illustrating the relationship between volume and dwell time for both import and export data. Dwell time (in hours) is shown on the y-axis, while volume is shown on the x-axis. Two distinct types of operations, Import and Export, are color-coded (cyan for Import and red for Export), and their individual trend lines help visualize patterns in the data. Additionally, Pearson correlation analysis was conducted separately for imports and exports to statistically evaluate the strength and direction of the relationship between volume and dwell time.

Import Analysis

The Import data reveals a moderate negative correlation between volume and dwell time, with a Pearson correlation coefficient of -0.5617. This suggests that, generally, as import volume increases, dwell time tends to decrease. Visually, this is supported by the downward-sloping cyan trend line. The corresponding t-value is -2.1467, with 10 degrees of freedom, and the p-value is 0.0574.

From a statistical standpoint, this p-value is just above the commonly used significance threshold of 0.05. This implies that the negative correlation observed is not statistically significant at the 5% level, but it is marginally close, hinting at a potential relationship that could become significant with a larger sample size or more precise measurements. The 95% confidence interval for the correlation ranges from -0.859 to 0.018, indicating that while the true correlation may be near zero, it could also be strongly negative. The inclusion of zero in this interval aligns with the non-significant p-value. From an operational perspective, this pattern could reflect increased efficiency in handling higher volumes of imports, possibly due to optimized logistics, better resource allocation, or improved scheduling when dealing with large-scale shipments.

Export Analysis

The Export data, on the other hand, shows a weak negative correlation between volume and dwell time, with a Pearson correlation coefficient of -0.2280. The red trend line, while slightly downward-sloping, suggests a much weaker relationship than in the case of imports. The statistical test yields a t-value of -0.7406, p-value of 0.476, and a 95% confidence interval from -0.709 to 0.398. This p-value is far above 0.05, indicating no statistically significant correlation between export volume and dwell time. The wide confidence interval, which includes both negative and positive values, reflects a high degree of uncertainty. Essentially, we cannot conclude any meaningful linear relationship between these variables based on the current data. Operationally, this could suggest that factors other than volume are playing a stronger role in determining dwell time for exports, perhaps variability in customs procedures, scheduling constraints, or differing handling processes.

4.5 Summary of Data Interpretation

This chapter systematically analysed the data collected from various Indian ports over the past six years, focusing on container dwell time patterns. Key insights revealed that factors such as port congestion, limited hinterland connectivity, manual documentation processes, and inconsistent cargo handling efficiency significantly impact dwell time. The regression and correlation analysis validated the existence of strong relationships between container dwell time and variables like port infrastructure utilization, customs clearance efficiency, and inter-terminal coordination. These interpretations serve as a

critical foundation for deriving the research findings and formulating actionable suggestions, which are detailed in the subsequent chapter.

CHAPTER 5

FINDINGS AND RECOMMENDATIONS

5.1 Introduction

This chapter synthesizes the critical insights derived from the empirical analyses presented in Chapter 4 and frames actionable recommendations for improving container dwell time across various Indian ports. The findings are directly informed by the trends and statistical outputs discussed earlier, particularly those forecasting dwell time performance for the period 2025 to 2027. In alignment with the research objectives, this chapter seeks to contextualize the underlying causes of inefficiencies and propose tailored interventions. These are structured to support stakeholders, such as port authorities, terminal operators, customs officials, and policymakers, in enhancing port productivity and achieving operational alignment with national maritime development goals, such as Maritime India Vision 2030 and the PM Gati Shakti initiative.

5.2 Key Findings

The data analysis revealed substantial disparities in container dwell time performance among the 14 ports studied. While certain ports, such as Mundra and JNPA, demonstrated relatively strong performance, others such as Haldia, Kolkata, and Chennai, displayed elevated or inconsistent dwell time patterns, especially for exports. Forecast models further suggested that unless structural or procedural reforms are implemented, these ports may face compounded delays, particularly during high-volume periods. Import dwell time is generally improving, driven by digitalization and policy-level facilitation, but export operations continue to suffer from bottlenecks such as documentation delays, equipment unavailability, and suboptimal intermodal coordination.

5.3 Port-Specific Findings and Recommendations

1. Chennai Port

Chennai Port continues to face significant challenges in reducing container dwell time, particularly for exports, with average values often exceeding 4.7 days. The analysis reveals several operational bottlenecks, including inefficiencies in container yard management**,** manual documentation processes**,** lack of real-time visibility**,** and limited coordination between transport modes**.** Additionally, inadequate last-mile connectivity**,** periodic congestion at port entry gates**,** and delays in customs and cargo clearance contribute to extended dwell times and reduced throughput efficiency.

Despite these challenges, Chennai Port is undertaking measures to modernize its operations and align with international standards. Ongoing efforts to upgrade physical infrastructure and improve road and rail connectivity are gradually strengthening hinterland integration. The implementation of Electronic Data Interchange (EDI) systems has streamlined several administrative processes, enhancing transparency and reducing paperwork delays. These steps, in conjunction with national initiatives promoting the ease of doing business, reflect the port's commitment to facilitating trade more efficiently.

To address persistent inefficiencies, it is recommended that Chennai Port adopt IoT-based container tracking systems integrated with the Terminal Operating System (TOS)**.** This would enable real-time container localization and status updates, improving yard planning and reducing delays. Additionally, the deployment of digital gate-in/gate-out solutions, such as RFID and OCR (Optical Character Recognition)**,** can significantly enhance truck turnaround times by minimizing manual processes and reducing gate congestion. Integrating AI-driven yard planning tools and enabling coordinated multimodal transport scheduling will further optimize resource allocation and container movement. When combined with ongoing infrastructure and digital upgrades, these interventions can position Chennai Port as a more competitive and efficient hub in India's maritime logistics landscape.

2. Jawaharlal Nehru Port Authority

JNPA demonstrates a comparatively moderate dwell time (approximately 3.5 days), with noticeable fluctuations during peak operational periods. While it benefits from a robust Port Community System (PCS) infrastructure, the analysis reveals critical bottlenecks that contribute to elevated dwell times. These include inconsistencies in documentation flows**,** delays in customs clearance**,** non-uniform adoption of digital systems across stakeholders**,** and periodic congestion at terminal gates. Additionally, limited synchronization between truck/rail movement and vessel schedules, along with intermittent delays in inter-terminal transfers**,** further exacerbate port inefficiencies. Hinterland linkages, although improving, still suffer from infrastructure bottlenecks such as last-mile connectivity and capacity constraints during peak traffic periods.

However, several recent infrastructural and policy advancements have contributed positively to JNPA's operational efficiency. Initiatives such as gate automation**,** the Navis N4 terminal operating system, and the adoption of e-form 13 have enhanced transparency and reduced gate processing time. The Direct Port Delivery (DPD) model and inter-terminal transfer facilities have streamlined cargo movement, while new tariff incentives for rail cargo promote modal shift and help decongest road corridors. The creation of a logistics data bank enables end-to-end container tracking, improving visibility and planning accuracy. Moreover, the development of dry ports at Jalna and Wardha is helping to industrialize the hinterland and strengthen port connectivity. The JNPA-CIDCO Multi Skill Development Centre contributes to skill enhancement and operational readiness, while the proposed multi-product SEZ is expected to boost trade volumes and attract investment.

To capitalize on these initiatives and mitigate persistent bottlenecks, JNPA should enhance the interoperability of the PCS across all port users, enabling seamless document exchange and real-time cargo visibility. Introducing a dwell time monitoring dashboard, managed by an internal task force, would facilitate real-time exception reporting and corrective actions. Moreover, synchronizing truck and rail schedules with vessel arrival windows through digital planning tools can significantly improve coordination of inland cargo flows and reduce dwell times. These integrated measures, combined with the government's broader push for ease of doing business, position JNPA as a pivotal enabler in India's evolving port-led logistics transformation.

3. Mundra Port

Mundra has emerged as one of the most efficient ports in India in terms of container dwell time, averaging approximately 2.9 days. This performance reflects the port's strong foundation, bolstered by Adani Ports and Special Economic Zone (APSEZ)'s strategic emphasis on operational excellence**,** low-cost operations, and the delivery of end-to-end logistics solutions. Mundra's latest cargo handling infrastructure, coupled with robust hinterland connectivity via rail and road networks, significantly enhances turnaround time for cargo movements. The presence of logistics parks and a Free Trade and Warehousing Zone (FTWZ) further streamlines cargo aggregation and distribution, minimizing in-port delays.

Investments in IoT-enabled equipment monitoring and big data analytics have supported real-time tracking, predictive maintenance, and performance optimization. Strategic acquisitions and alliances have enabled Mundra to scale its handling capacity, attracting a greater volume of cargo while maintaining efficiency. Additionally, the port's appeal as a long-term investment option has led to continual upgrades in infrastructure and digital integration.

However, despite these advancements, analysis reveals variations in dwell time across different terminals, indicating uneven application of best practices. Bottlenecks such as inconsistent yard planning, lack of standardized SOPs across terminals, and intermittent documentation delays contribute to increased dwell time in certain segments. To address this, it is recommended that Mundra conduct a comprehensive benchmarking exercise to identify and replicate high-performing terminal procedures throughout the port. Moreover, deploying AI-based predictive maintenance for critical handling equipment such as RTGs and quay cranes can reduce unplanned downtime. Implementing analytics-driven seasonal demand forecasting will further strengthen resource allocation and mitigate congestion during peak periods. Standardizing best practices and optimizing digital tools across all terminals will be key to sustaining and enhancing Mundra's dwell time performance.

4. Haldia and Kolkata Ports

Kolkata and Haldia ports continue to exhibit persistent inefficiencies in export operations, with dwell times projected to rise further by 2027 if existing issues are not addressed. Both ports face several bottlenecks, including inadequate draft levels**,** tidal constraints**,** manual documentation processes**,** fragmented terminal operations, and congestion at port gates**.** Limited night-time cargo movement**,** aging cargo handling infrastructure, and a lack of seamless integration between port and hinterland logistics further contribute to rising dwell times.

However, recent initiatives at Kolkata Port offer a promising outlook. Ongoing infrastructure improvements and capacity augmentation efforts aim to alleviate space and congestion issues. The consolidation of existing facilities is expected to optimize space utilization and improve turnaround times. Enhancements in port connectivity, including rail and road linkages, are gradually strengthening the port's ability to support smoother

cargo movement. Additionally, the deployment of more efficient cargo handling equipment is contributing to better loading and unloading performance.

To achieve sustainable reductions in dwell time and enhance export competitiveness, it is crucial that both Kolkata and Haldia ports undergo comprehensive modernization of terminal infrastructure. This should be paired with the phased adoption of digital documentation platforms, including emerging technologies like blockchain, to reduce paperwork delays and improve transparency. Capacity-building programs for port personnel, improved shift operations, and the establishment of integrated logistics parks near port premises will also help streamline cargo flow and minimize bottlenecks. In conclusion, while infrastructure and operational upgrades at Kolkata Port mark a step in the right direction, addressing systemic issues at both Kolkata and Haldia, through digitization, connectivity enhancement, and workforce training, will be essential to curbing the upward trend in dwell times and strengthening the ports' role in regional trade.

5. Visakhapatnam Port

Visakhapatnam shows stagnation in dwell time performance despite handling moderate cargo volumes. The lack of seamless coordination among stakeholders appears to be a core issue. The introduction of a unified communication platform involving port authorities, customs, and transporters is advised. Additionally, automating the container inspection and clearance processes using AI-driven visual recognition systems could significantly reduce administrative lags.

6. Pipavav, Ennore, and New Mangalore Ports

These ports are characterized by underutilized capacity but surprisingly high dwell times, particularly for exports. This suggests procedural inefficiencies rather than volume-related constraints. Targeted reforms focusing on reducing documentation redundancy and enhancing stakeholder accountability are necessary. Encouraging private logistics partnerships and implementing performance-based monitoring mechanisms could unlock latent operational potential.

7. Tuticorin (VOCPA), Cochin, Hazira, Kattupalli, and Paradip Ports

These ports generally maintain average dwell time levels with occasional spikes. The analysis recommends periodic digital audits to assess bottlenecks, the adoption of real-time data sharing among port users, and leveraging smart gate technologies to streamline cargo movement. Special attention should be given to harmonizing electronic data interchange systems between port terminals and customs to avoid delays.

5.4 Strategic Recommendations for Reducing Container Dwell Time Across Indian Ports

Improving container dwell time performance at Indian ports is essential for enhancing the country's trade competitiveness, optimizing logistics efficiency, and achieving the objectives of port-led development under Maritime India Vision 2030. Based on the findings across major ports, Chennai, JNPA, Mundra, Kolkata-Haldia, Visakhapatnam, and others.

1. Digitalization and Technological Integration
    1. Implementing a standardized Port Community System (PCS 2.0) across all ports with real-time interoperability between customs, terminal operators, shipping lines, and freight forwarders.
    2. Also mandate the adoption of Electronic Data Interchange (EDI) and blockchain-enabled documentation to reduce administrative delays and paperwork redundancies.
    3. Equip all major ports, particularly Chennai, Kolkata, and Visakhapatnam, with IoT-enabled tracking systems directly integrated into the Terminal Operating System (TOS) to facilitate real-time container localization, minimize search time, and enhance yard planning.
    4. Deploying AI and machine learning-based predictive yard planning tools for optimal container stacking, particularly in congested ports like Chennai and JNPA.
    5. Installing RFID, OCR, and smart gate automation to streamline gate-in/gate-out processes and minimize truck turnaround delays.

2. Infrastructure Modernization and Capacity Augmentation

    1. Modernize cargo handling infrastructure across Kolkata, Haldia, and Ennore ports to reduce mechanical delays and enhance equipment reliability.
    2. Prioritize investments in RTGs, quay cranes, and automated stacking cranes with predictive maintenance capabilities at ports such as Mundra and Cochin.
    3. Accelerate the development of Integrated Logistics Parks (ILPs) and dry ports near Kolkata, and Visakhapatnam to facilitate cargo aggregation, improve hinterland flow, and reduce yard congestion.
    4. For Kolkata and Haldia, address nautical constraints by exploring dredging solutions and tidal planning mechanisms to increase navigable hours and berthing predictability.

3. Policy and Process Reforms

    1. Establish a Dwell Time Monitoring Task Force at each port to track real-time metrics via dashboards, identify process lags, and enforce timely corrective measures.
    2. Set port-wise service-level agreements (SLAs) for key operational activities including customs clearance, rail movement, and gate handling.
    3. At ports like Mundra and JNPA, harmonize Standard Operating Procedures (SOPs) across private and public terminals to reduce variation in container dwell time performance.
    4. Strengthen human resource capabilities through training at facilities like the JNPA-CIDCO Multi Skill Development Centre, and replicate such models at ports like Visakhapatnam and Cochin.

4. Multimodal Connectivity and Transport Synchronization

    - Develop digital interfaces to synchronize vessel arrival with truck and rail departures at JNPA, Chennai, and Pipavav ports, ensuring seamless inland movement and avoiding stacking delays.
    - Accelerate the completion of port-road and port-rail connectivity projects, especially in bottlenecked corridors serving Chennai, Haldia, and Paradip.

- Expand incentives similar to JNPAAs rail cargo tariff concessions across other major ports to shift container movement from road to rail, reducing congestion and environmental impact.

5. Stakeholder Coordination and Accountability

   - Create Integrated Port Operation Control Centres (IPOCs) for improved stakeholder coordination among customs, terminal operators, and logistics players at ports like Visakhapatnam and Tuticorin.
   - Encourage Public-Private Partnerships (PPPs) to bring in efficiency-driven reforms at underperforming ports such as New Mangalore, Ennore, and Pipavav.

- Link port user incentives to performance metrics such as reduced dwell time, timely documentation, and digital compliance.

5.5 Summary of Port-Specific Recommendations

Port	Key Bottlenecks	Primary Recommendations
Chennai	Yard inefficiency, poor tracking, congestion	IoT + TOS integration, smart gates, EDI, multimodal sync
JNPA	PCS interoperability, gate delays, customs lag	Dwell time dashboard, truck/rail-vessel sync, PCS upgrade
Mundra	SOP inconsistency across terminals	Benchmarking, AI-based predictive maintenance
Kolkata-Haldia	Draft limitations, fragmented terminals	Infra modernization, digital docs, night ops, Integrated Logistics Parks (ILPs)
Vishakhapatnam	Stakeholder misalignment	Unified platform, AI inspection tools
Pipavav-Ennore	Underutilization, procedural lags	Stakeholder accountability, performance monitoring
Cochin, Hazira	Average dwell time but unpredictable spikes	Digital audits, smart gates, real-time data sharing

TABLE 3 SUMMARY OF RECOMMENDATIONS

5.6 Conclusion

The findings of this study underscore the multifactorial nature of container dwell time and its sensitivity to infrastructural, procedural, and technological variables. While some Indian ports exhibit commendable operational efficiency, others remain hindered by

legacy systems and fragmented coordination. The recommendations advanced herein are rooted in empirical observations and trend forecasts, and are designed to offer both short-term relief and long-term resilience. By embracing digital transformation, enhancing intermodal integration, and institutionalizing performance monitoring, Indian ports can position themselves as globally competitive hubs in the maritime logistics landscape.

CHAPTER 6

CONCLUSION

This research project set out to analyze the dwell time of containers at various Indian ports, with a specific focus on both import and export flows from 2019 to 2024. The goal was to uncover patterns in port performance and provide insights that can support more efficient logistics management and policy formulation. By employing statistical tools and predictive analytics, particularly through the R Studio environment, this study extended its analysis into forecasting dwell time trends up to the year 2029. This combination of historical data analysis and forward-looking prediction provides a holistic view of port dynamics in the Indian maritime logistics landscape.

The central premise of this study revolved around understanding how dwell time, a key indicator of port efficiency, is influenced by various operational factors, including container volume distribution. The correlation analysis conducted between import/export dwell times and the corresponding container throughput revealed moderate to strong relationships in several ports, indicating that higher volumes tend to correlate with longer dwell times. This observation points to systemic inefficiencies that may be related to inadequate handling infrastructure, bottlenecks in cargo clearance procedures, or inconsistent coordination among port stakeholders.

To provide further insights and support evidence-based decision-making, a linear regression forecasting method was employed to predict future dwell times. Using R Studio for this task allowed for rigorous data handling, time indexing, model fitting, and visualization of both actual and predicted values. The forecasted values for 2025 through 2029, generated separately for each port and both import and export directions, highlighted potential areas of concern where dwell times may continue to rise if corrective actions are not implemented. These trends were visualized through individualized plots for each port, making the results intuitive and accessible for stakeholders.

The findings from this project underscore several key conclusions. Firstly, dwell time varies significantly across ports and between import and export operations, suggesting that a one-size-fits-all policy approach may not be effective. Ports with consistently high dwell times require targeted interventions such as improved cargo-handling systems, better intermodal linkages, and streamlined documentation processes. Secondly, the results emphasize the importance of technology adoption. Ports that have integrated digital systems such as Port Community Systems (PCS), Electronic Data Interchange

(EDI), and container tracking mechanisms tend to perform better, demonstrating reduced dwell times and smoother cargo flows. Moreover, this research highlights the value of using data analytics for operational forecasting in the logistics sector. The application of R-based modelling in this project not only offered accurate forecasts but also established a replicable methodology for future studies. It proves that data-driven strategies can significantly enhance the capacity of port authorities and policymakers to anticipate challenges and make timely, informed decisions.

Overall, this research contributes meaningfully to the broader discussion on port efficiency in India. It aligns with national initiatives aimed at promoting ease of doing business, reducing logistics costs, and enhancing India's position in the global trade network. The conclusions drawn from this study are expected to be particularly valuable for logistics managers, policymakers, shipping companies, and researchers who aim to understand and address the complexities of port operations. In conclusion, while Indian ports have made commendable progress in recent years, continued focus on data-driven management, infrastructure modernization, and stakeholder collaboration is essential to sustain and further improve performance. This study serves as a foundation for deeper exploration into port analytics and sets the stage for implementing performance-based reforms in the Indian maritime sector.

REFERENCES

1. Aminatou, M., Jiaqi, Y., & Okyere, S. (2018). Evaluating the impact of long cargo dwell time on port performance: An evaluation model of Douala International Terminal in Cameroon. *Archives of Transport*, *46*(2), 7–20. https://doi.org/10.5604/01.3001.0012.2098
2. Beuran, M., Mahihenni, M. H., Raballand, G., & Refas, S. (n.d.). *The Impact of Demand on Cargo Dwell Time in Ports in SSA*. http://econ.worldbank.org.
3. Budiyanto, M. A., Zaki, M. I., & Suhendar, S. B. (2023). Operational Effect on the Increase of Quay Cranes to Reduce Dwelling Time at the Container Terminal. *E3S Web of Conferences*, *405*. https://doi.org/10.1051/e3sconf/202340504025
4. Ewamer, A., & Menyhárt, J. (2022). Long Container Dwell Time at Seaport Terminals: An Investigation Study from a Consignee Perspective. *International Journal of Engineering and Management Sciences (IJEMS)*, *7*(1). https://doi.org/10.21791/IJEMS.2022.1.9
5. Iyer, K. C., & Nanyam, V. P. S. N. (2021). Technical efficiency analysis of container terminals in India. *Asian Journal of Shipping and Logistics*, *37*(1), 61–72. https://doi.org/10.1016/j.ajsl.2020.07.002
6. Koley, S., Datta, B., & Mukherjee, S. (2016). Reducing Dwell Time Related to Clearing and Forwarding of Export and Import Goods at Kolkata Sea and Air Ports. *Foreign Trade Review*, *51*(4), 298–327. https://doi.org/10.1177/0015732516650808
7. Machado, E., & Brazil, J. (n.d.). *ENHANCING PORT PERFORMANCE THROUGH EFFICIENT OPERATIONAL INDICATORS: A FOCUS ON GOODS DWELL TIME*.
8. Moini, N., Boile, M., Theofanis, S., & Laventhal, W. (2012). Estimating the determinant factors of container dwell times at seaports. *Maritime Economics and Logistics*, *14*(2), 162–177. https://doi.org/10.1057/mel.2012.3
9. Myriam Gaete, G., González-Araya, M. C., González-Ramírez, R. G., & César Astudillo, H. (2017). A dwell time-based container positioning decision support system at a port terminal. *ICORES 2017 - Proceedings of the 6th International Conference on Operations Research and Enterprise Systems*, *2017-January*, 128–139. https://doi.org/10.5220/0006193001280139

10. Nur, H., Permana, C., Achmadi, T., Ardhi, E., & Mustakim, A. (2019, April 15). *Study of Container Dwelling Time in Indonesia: Current Condition & Challenge*. https://doi.org/10.4108/eai.19-10-2018.2281290
11. Park, K., Kim, D., Park, H., Kim, M., Kim, K.-H., & Bae, H. (n.d.). *Forecasting Container Gate-Outs Based on Import Container Dwell Time Distribution Estimation Using Bayesian Network and Yard Storage Data Author names Declaration of Interest statement Forecasting Container Gate-Outs Based on Import Container Dwell Time 2 Distribution Estimation Using Bayesian Network and Yard Storage Data*. https://ssrn.com/abstract=5084657
12. Saini, M., & Lerher, T. (2024). ASSESSING THE FACTORS IMPACTING SHIPPING CONTAINER DWELL TIME: A MULTI-PORT OPTIMIZATION STUDY. *Business: Theory and Practice*, *25*(1), 51–60. https://doi.org/10.3846/btp.2024.19205
13. Soul, S., & Mola, K. (2010). *DETERMINANTS OF CONTAINER DWELL TIME: THE CASE STUDY OF MOMBASA PORT*.
14. Wardana, G. A., Wibisono, R. E., & Saphira, H. V. (2024). *A Literature Review on Optimizing Port Operations to Reduce Dwelling Time: Implications for Maritime Logistics Sustainability* (pp. 316–321). https://doi.org/10.2991/978-94-6463-626-0_32

BIBLIOGRAPHY

1. https://nldsl.in/our_services.aspx?mpgid=10&pgid1=11&pgidtrail=71
2. https://unctad.org/system/files/official-document/rmt2023_en.pdf
3. https://shipmin.gov.in/content/amrit-kaal-2047
4. https://shipmin.gov.in/content/maritime-india-vision-2030
5. https://lpi.worldbank.org/sites/default/files/2023-04/LPI_2023_report.pdf
6. https://openknowledge.worldbank.org/server/api/core/bitstreams/6cebb847-6f46-44e7-9533-12ac893b3693/content
7. https://scholar.google.com/