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IMPACT OF PORT DWELL TIME ON OVERALL SUPPLY CHAIN IN INDIA

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Abstract: This study examines the impact of port dwell time delays on import lead time volatility in Indian logistics operations using primary data collected from 44 freight forwarding professionals. The analysis integrates descriptive statistics, weighted mean scoring, and chi-square tests to evaluate delay frequency, operational impacts, and statistical associations. Findings indicate that dwell time delays are a structural issue, significantly contributing to delivery schedule disruptions and increased logistics costs. The study also explores the influence of eastern sea route dependency, revealing strong perceptual alignment but limited statistical significance due to sample constraints. The results highlight the need for improved port efficiency, digital clearance systems, and strategic infrastructure development to enhance supply chain reliability.

Keywords: Port Dwell Time, Import Lead Time Volatility, Indian Ports, Freight Forwarding, Supply Chain Disruptions, Demurrage and Detention Costs, Port Congestion, Logistics Performance, Eastern Sea Route Dependency, Andaman Sea Corridor

I. INTRODUCTION

International trade plays a crucial role in economic growth and industrial development, particularly for emerging economies like India. Imports enable domestic industries to access essential raw materials, machinery, and technology that are not sufficiently available within the country. With increasing integration into global supply chains, India has witnessed a significant rise in import volumes and operational complexity. As a result, the efficiency of logistics and supply chain systems has become a key determinant of trade competitiveness and economic performance.

Ports serve as the primary interface between maritime transport and inland logistics, making their efficiency critical to import operations. One of the most important indicators of port performance is dwell time, which refers to the duration cargo remains at the port before clearance. Prolonged dwell time leads to congestion, increased costs, and operational uncertainty. Despite infrastructure improvements, Indian ports continue to face challenges such as procedural delays, documentation inefficiencies, and coordination issues among stakeholders, resulting in inconsistent port performance.

A major consequence of extended dwell time is the volatility it introduces in import lead time, affecting delivery predictability and supply chain planning. When delays become unpredictable, firms are forced to maintain higher safety stock and incur additional costs. Furthermore, India's dependence on eastern maritime routes, particularly those connected to the Andaman Sea, influences cargo flow concentration and port congestion patterns. This study therefore focuses on analysing the impact of port dwell time on import lead time.

Given the increasing importance of efficient import logistics, it becomes essential to examine the underlying causes and implications of port-related delays. Understanding how dwell time influences lead time variability can provide valuable insights for improving operational planning and reducing inefficiencies. This study seeks to contribute to this understanding by analysing practitioner-level experiences and identifying key areas where improvements in port operations and logistics coordination can enhance overall supply chain reliability.

II. OBJECTIVES OF THE STUDY

The objective of the present study is to examine the impact of port dwell time delays on the performance of import logistics in India. The study focuses on understanding how delays at ports influence delivery timelines, operational efficiency, and overall supply chain reliability. It also aims to analyse the key factors contributing to dwell time and the resulting variability in import lead time.

In addition, the study explores the broader operational and strategic implications of these delays, including cost impacts and logistics disruptions. It further seeks to examine the role of eastern sea route dependency, particularly the Andaman Sea corridor, in influencing port congestion and dwell time patterns, based on insights gathered from logistics professionals.

Objectives:

1. To assess the extent, frequency, and key causes of port dwell time delays in Indian import operations.
2. To evaluate the effect of port dwell time delays on the variability of import lead time in India.
3. To analyse the operational and cost implications arising from port dwell time delays in import logistics.
4. To examine the perceived influence of eastern sea route dependency (Andaman Sea corridor) on port congestion and dwell time patterns.

III. REVIEW OF LITERATURE

The review of literature indicates that port dwell time has been widely recognised as a critical determinant of logistics efficiency and supply chain performance. The conceptual foundation is established by Notteboom (2006), who highlights dwell time as a key performance variable influencing port competitiveness and emphasises the importance of time reliability over mere cost advantages. Similarly, Tongzon (2009) reinforces the idea that transit time predictability plays a crucial role in port selection decisions, indicating that variability in dwell time significantly affects logistics planning.

The relationship between dwell time and lead time variability is further supported by supply chain studies such as Hines (2004), which explains how fluctuations in lead time increase inventory holding costs and disrupt operational planning. Jiang, Li and Guo (2014) provide empirical evidence showing that variability in dwell time directly impacts delivery schedule reliability and propagates disruptions across the supply chain. These studies collectively establish that dwell time delays are not isolated operational issues but have broader implications for supply chain stability and performance.

In the context of port operations and efficiency, the World Bank (2010) defines dwell time as a key indicator of port performance and highlights that delays are significantly higher in developing economies due to procedural inefficiencies. Studies focusing on India, such as Bhatt and Bhatt (2012) and Raghuram and Deepa (2018), identify major causes of dwell time delays including customs clearance inefficiencies, documentation delays, and lack of coordination among multiple regulatory agencies. Nair, Bhanu and Rao (2015) further emphasise variations in port efficiency across regions, indicating that operational and administrative factors play a significant role in determining dwell time outcomes.

From a broader perspective, Munim and Schramm (2018) analyse the relationship between port performance, infrastructure, and logistics efficiency, concluding that administrative improvements are as important as physical infrastructure development. Djankov, Freund and Pham (2010) quantify the

economic impact of delays, demonstrating that even minor increases in time can significantly reduce trade efficiency and increase costs. These studies underline the macroeconomic importance of improving port performance and reducing dwell time.

The literature also incorporates the concept of supply chain resilience, as discussed by Christopher and Peck (2004), who highlight the importance of flexibility and contingency planning in managing logistics disruptions. Firms often respond to dwell time delays through strategies such as buffer inventory and alternative routing, which, while effective, increase operational costs. This reinforces the need for addressing the root causes of delays rather than relying solely on reactive measures.

Arvis et al. (2018), through the World Bank's Logistics Performance Index (LPI), provide a global benchmarking framework for assessing logistics efficiency across countries. The study highlights that customs efficiency, infrastructure quality, and timeliness of shipments are key determinants of logistics performance. India's ranking in the LPI indicates improvements in infrastructure but persistent challenges in customs procedures and shipment reliability. The findings reinforce the importance of reducing dwell time and improving clearance efficiency to enhance overall logistics performance and global trade competitiveness.

Finally, emerging research by Lee and Lam (2016) explores the significance of the Andaman Sea corridor as an important maritime route influencing cargo flows between India and Southeast Asia. The study suggests that route concentration and vessel movement patterns can contribute to congestion at specific ports, indirectly affecting dwell time. However, limited empirical research exists on this aspect, particularly from a practitioner perspective.

Overall, the reviewed literature provides a strong theoretical and empirical base linking port dwell time to lead time volatility, operational inefficiencies, and supply chain disruptions. At the same time, it highlights gaps in terms of primary data-based insights and limited exploration of route dependency effects, which the present study seeks to address.

IV. RESEARCH METHODOLOGY

This study adopts a **Mixed-method research design** combining both qualitative and quantitative approaches to analyse the impact of port dwell time delays on import lead time volatility in India. The research is descriptive and analytical in nature, focusing on identifying the extent and causes of dwell time delays and evaluating their effect on delivery timelines and overall supply chain performance. An exploratory component is also included to examine the perceived influence of eastern sea route dependency on port congestion patterns.

The study is based on both primary and secondary data. Primary data was collected through structured interviews with 44 freight forwarding and import logistics professionals who are directly involved in port clearance, documentation, and shipment coordination. A structured questionnaire consisting of 21 questions was used to capture insights related to delay frequency, operational challenges, cost implications, and logistics planning. Secondary data was sourced from industry reports, academic literature, and publicly available port performance data to support and contextualise the findings.

Purposive sampling was employed to select respondents based on their professional expertise and relevance to the research topic. As the sample consists of experienced practitioners rather than a random population, the findings are interpreted as indicative of industry practices and perceptions rather than statistically generalisable. The sample includes respondents with varied experience levels and roles, ensuring a balanced perspective across operational and strategic dimensions of import logistics.

The data collected was analysed using **Descriptive statistics, Weighted mean analysis, and Chi-square tests** of association. Descriptive statistics were used to present frequency distributions and response patterns, while weighted mean analysis was applied to ordinal data to assess the intensity of responses. Chi-square tests were conducted at a 5 percent level of significance to examine relationships between key

variables such as delay frequency, lead time variability, and port-level differences. This analytical framework enables both pattern identification and statistical validation of the study's findings.

V. DATA ANALYSIS AND INTERPRETATION

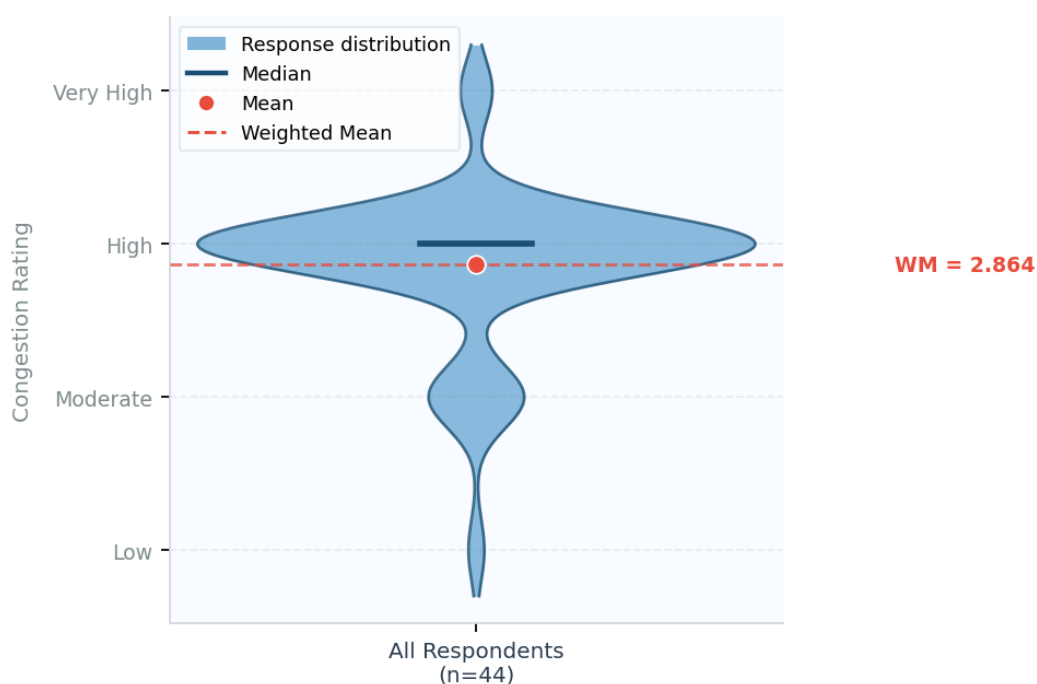
Table 5.1: Port Congestion Level Affecting Clearance Timelines

The following diagram analyses the perceived level of port congestion and its impact on cargo clearance timelines. It presents the distribution of responses across different congestion levels, indicating the extent to which congestion affects import operations.

Congestion Level	Scale value	Number of respondents	Percentage %
Low	1	2	4.5
Moderate	2	5	11.4
High	3	28	63.6
Very high	4	9	20.5
Total	-	44	100

Figure 5.1

Q9 – Port Congestion Level Affecting Clearance Timelines



Description:

The above diagram presents the distribution of responses regarding port congestion levels affecting clearance timelines, using a violin plot to illustrate the spread and concentration of responses across different rating categories. It also highlights the median, mean, and weighted mean values to provide a comprehensive view of response intensity among logistics professionals.

Interpretation:

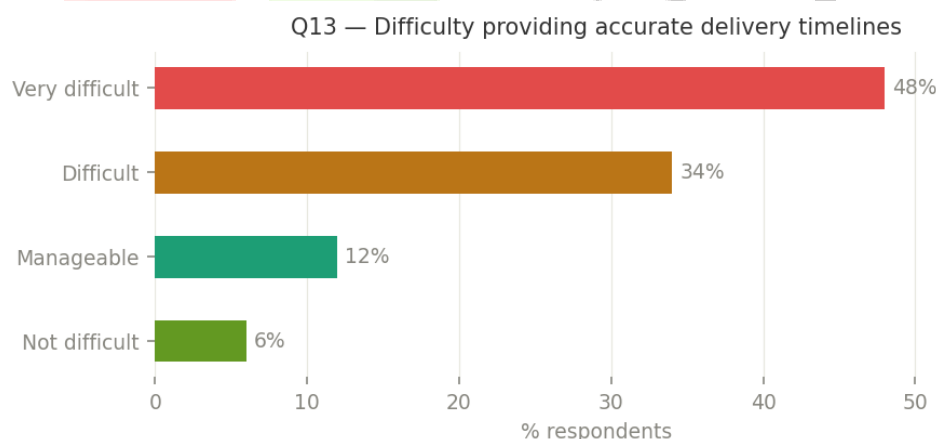
The diagram indicates that a majority of responses are concentrated around the “High” congestion level, with the weighted mean of 2.864 reinforcing this observation. This suggests that port congestion is perceived as a significant and consistent challenge affecting clearance timelines. The limited spread towards lower congestion levels further confirms that congestion is not occasional but a common operational issue across ports.

Table 5.2: Difficulty in Predicting Delivery Timelines

The following diagram examines the level of difficulty faced by logistics professionals in predicting delivery timelines. It reflects the impact of operational uncertainties, particularly port delays, on shipment planning and schedule accuracy.

Difficulty level	Respondents	Percentage %
Very Difficult	21	48
Difficult	15	34
Manageable	5	12
Not difficult	3	6
Total	44	100

Figure 5.2

**Description:**

The above diagram illustrates the level of difficulty experienced by logistics professionals in providing accurate delivery timelines. It presents the percentage distribution of responses across different difficulty levels, highlighting the extent of uncertainty in shipment planning. The chart categorises responses from “not difficult” to “very difficult,” allowing a clear comparison of how widespread the issue is across the sample. This provides a visual representation of how consistently delivery prediction challenges are faced in import logistics.

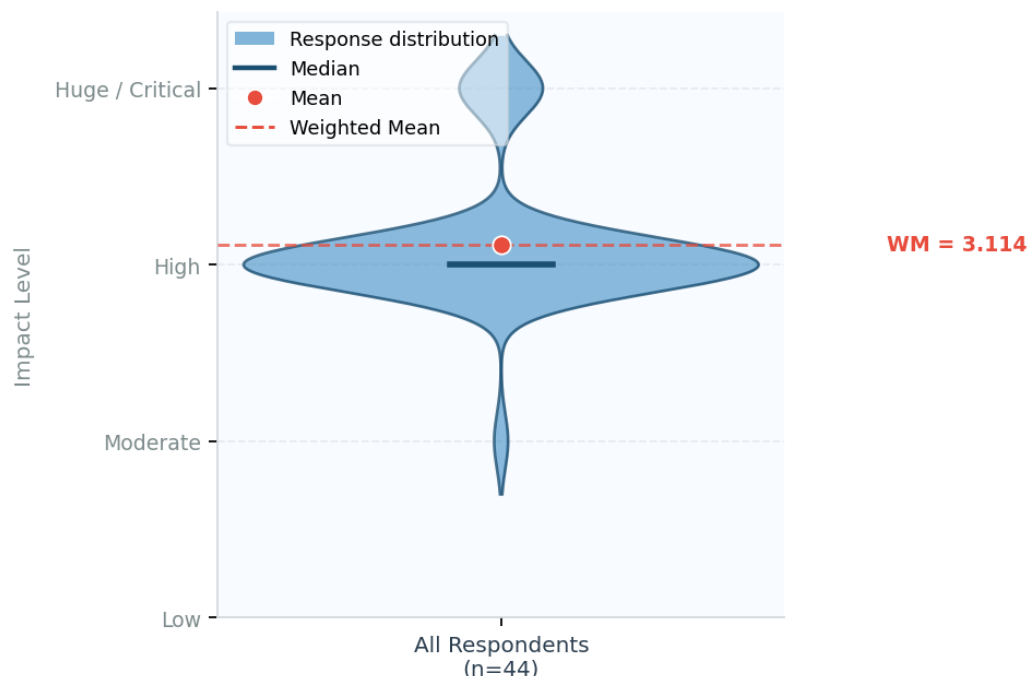
Interpretation:

The diagram indicates that a majority of respondents find it difficult or very difficult to provide accurate delivery timelines, with 48% reporting it as “very difficult” and 34% as “difficult.” This clearly reflects a high degree of uncertainty in import operations, primarily driven by port-related delays and operational inefficiencies. The relatively small proportion of respondents reporting manageable or low difficulty further confirms that delivery predictability remains a significant challenge. Overall, the findings suggest that timeline estimation is not a situational issue but a persistent and systemic limitation within the logistics framework.

Table 5.3: Cost Impact of Port Dwell Time Delays

The following diagram analyses the financial impact of port dwell time delays on import operations. It highlights the severity of cost implications such as demurrage, detention, and additional logistics expenses.

Impact level	Scale	Respondents	Percentage %
Low	1	0	0
Moderate	2	1	2.3
High	3	25	56.8
Huge/Critical	4	18	40.9
Total	-	44	100

Figure 5.3**Q14 – Impact of Dwell Time Delays on Demurrage & Detention Costs****Description:**

The above diagram presents the distribution of responses regarding the impact of dwell time delays on demurrage and detention costs, using a violin plot to illustrate the spread and concentration of responses across different impact levels. It highlights key statistical indicators such as the median, mean, and weighted mean to provide a comprehensive understanding of response intensity. The categorisation of responses from “low” to “huge/critical” enables a clear assessment of the severity of cost implications faced by importers.

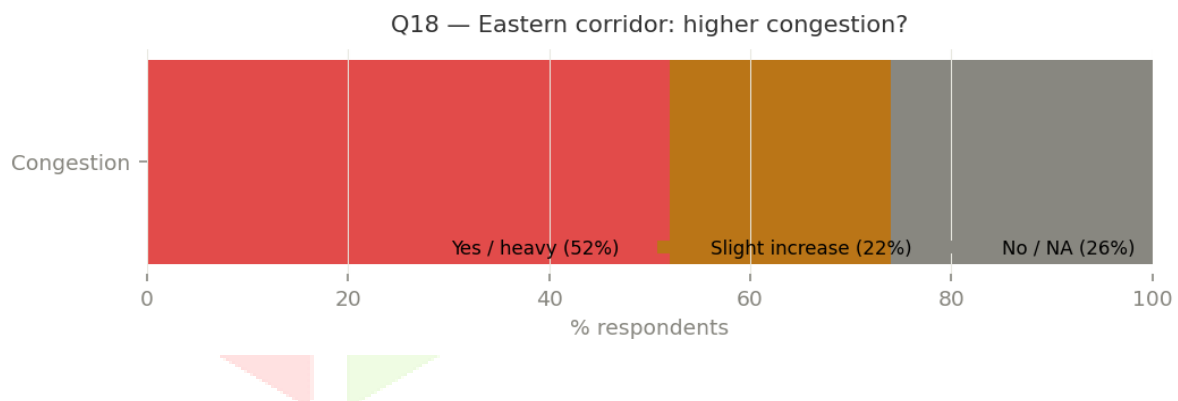
Interpretation:

The diagram indicates that a majority of responses are concentrated around the “high” to “huge/critical” impact levels, with a weighted mean of 3.114 reinforcing the severity of cost implications. This suggests that dwell time delays result in significant financial burdens, particularly in the form of demurrage and detention charges. The limited distribution towards moderate or low impact levels further confirms that these costs are not occasional but consistently high across import operations. Overall, the findings highlight that financial impact is both substantial and widespread, making cost escalation a critical consequence of port delays.

Table 5.4: Impact of Eastern Sea Route Dependency on Port Congestion

The following diagram evaluates the perceived influence of eastern sea route dependency on port congestion levels. It reflects how concentration of cargo flows through specific maritime routes contributes to operational pressure on ports.

Response	Category	Respondents	%
Yes / Heavy Impact	23	52	52
Slight Increase	10	22	22
No / NA	11	26	26
Total	44	100	100

**Description:**

The above diagram illustrates the perceived impact of eastern sea route dependency on port congestion levels. It presents the percentage distribution of responses across three categories- “yes/heavy,” “slight increase,” and “no/NA”-providing a clear view of how logistics professionals assess congestion arising from eastern corridor cargo flows. The visual representation enables comparison of the extent to which route concentration influences operational pressure at ports.

Interpretation:

The diagram indicates that a majority of respondents (52%) perceive a heavy impact of eastern sea route dependency on port congestion, while an additional 22% observe a slight increase. This suggests that a significant portion of import cargo routed through the eastern corridor contributes to congestion at receiving ports. Although 26% of respondents do not observe a direct impact, the overall distribution highlights a strong perception of route-driven congestion. These findings support the view that cargo concentration along specific maritime routes plays a role in shaping dwell time patterns and port efficiency.

VI. RESULTS AND DISCUSSION

6.1 RESULTS

The analysis of primary data indicates that port congestion is a significant and consistent factor affecting clearance timelines in Indian import operations. A majority of respondents rated congestion levels as high, with a weighted mean score of 2.864 on a four-point scale. The distribution of responses shows a strong concentration in the higher categories, indicating that congestion is not an occasional issue but a regularly experienced operational constraint.

The results further demonstrate a high level of difficulty in predicting delivery timelines. Approximately 82% of respondents reported that providing accurate delivery estimates is either difficult or very difficult, with 48% categorising it as very difficult. This indicates a substantial level of uncertainty in logistics planning, suggesting that delays at ports directly contribute to variability in import lead time.

In terms of financial impact, the findings reveal that dwell time delays impose a severe cost burden on importers. The majority of respondents rated the impact as high to critical, with a weighted mean of 3.114. The response distribution shows minimal representation in lower impact categories, indicating that demurrage and detention costs are consistently significant across import operations. This confirms that financial consequences are both widespread and substantial.

The analysis also highlights the perceived impact of eastern sea route dependency on port congestion. A total of 74% of respondents indicated either a heavy or moderate increase in congestion due to cargo routed through the eastern corridor, while 26% reported no significant impact. This suggests that route concentration contributes to operational pressure at ports, although the degree of influence varies across respondents.

Overall, the results indicate that port dwell time delays have a statistically consistent and multidimensional impact on import logistics. The clustering of responses in higher severity categories across variables such as congestion, timeline difficulty, and cost impact suggests that these issues are systemic in nature. The findings confirm that delays are not isolated events but form an integral part of the current logistics environment, significantly affecting efficiency, predictability, and cost structures.

6.2 DISCUSSIONS

The findings of the study indicate that port dwell time delays in India are structural in nature, driven primarily by congestion, procedural inefficiencies, and coordination gaps. The high weighted mean for congestion and the clustering of responses in higher categories confirm that delays are a persistent operational reality. Addressing this issue requires targeted interventions at both the process and infrastructure levels. One of the most critical solutions identified through expert responses is the implementation of pre-clearance systems, allowing documentation and regulatory approvals to be completed before vessel arrival. This directly addresses the primary cause of delays and has the potential to significantly reduce dwell time.

The study also highlights the strong link between congestion and delivery timeline uncertainty, with a majority of respondents reporting difficulty in predicting shipment timelines. This unpredictability can be mitigated through improved digital integration and real-time tracking systems. The adoption of a unified digital clearance platform integrating customs, FSSAI, and port authorities can streamline processes, reduce manual intervention, and improve transparency. Additionally, the introduction of predictive analytics and digital tracking tools can enhance visibility across the supply chain, enabling logistics professionals to make more accurate delivery estimations.

From a capacity and operations perspective, the persistence of congestion suggests the need for continuous port operations and better utilisation of existing infrastructure. Respondents emphasised the importance of 24/7 port functioning to prevent cargo accumulation during non-operational hours. Furthermore, port-specific dwell time audits can help identify unique bottlenecks at major ports such as Chennai, JNPT, and Vizag, allowing for customised solutions rather than a one-size-fits-all approach. Seasonal congestion

calendars, particularly during peak periods such as festive and year-end cycles, can also enable proactive planning and reduce operational strain.

The financial impact of dwell time delays, as reflected in the high weighted mean for cost, indicates that businesses are consistently incurring significant demurrage, detention, and contingency logistics expenses. While structural improvements are essential, firms must also adapt their operational strategies to manage these costs effectively. The findings suggest that importers should incorporate buffer time into planning, adopt port-specific logistics strategies, and treat contingency logistics as a fixed operational cost rather than an exception. These measures can improve resilience while long-term systemic improvements are implemented.

The role of eastern sea route dependency in contributing to congestion highlights the importance of strategic planning at a broader logistics network level. The concentration of cargo flows through specific maritime routes creates uneven pressure on ports, leading to increased dwell time. To address this, infrastructure development and surge capacity planning at eastern ports such as Chennai, Kattupalli, and Vizag are essential.

The study also reveals that current coping mechanisms are largely reactive, focusing on managing delays rather than preventing them. This underscores the need for a shift from operational adjustments to systemic reforms. Policy-level interventions, including simplification of customs procedures, reduction of manual documentation, and enhanced inter-agency coordination, are critical to achieving sustainable improvements. The strong alignment in practitioner responses further indicates that the industry has a clear and unified understanding of the problem and the required solutions.

Additionally, the respondents, based on their professional experience in import logistics, suggested several practical measures to address port dwell time delays and improve overall supply chain efficiency.

- Implement pre-clearance systems to complete documentation before vessel arrival. This would reduce idle time at ports by ensuring regulatory approvals are completed in advance, thereby accelerating cargo clearance.
- Introduce 24/7 port operations to avoid cargo accumulation during non-working hours. Continuous operations can significantly reduce backlog and improve turnaround time, especially during high-volume periods.
- Develop seasonal congestion calendars for peak periods such as festivals and year-end cycles. This would enable better planning and proactive scheduling, helping stakeholders anticipate and manage surges in cargo volume.
- Conduct port-specific dwell time audits to identify unique bottlenecks. Such audits can provide targeted insights for each port, allowing customised solutions instead of generalized improvements.
- Create a unified digital clearance platform integrating customs, FSSAI, and port authorities. This would streamline documentation processes, reduce duplication, and improve coordination among regulatory agencies.
- Reduce manual intervention through increased automation in port processes. Automation can enhance efficiency, minimise human errors, and speed up cargo handling and clearance procedures.
- Diversify cargo routing to reduce dependency on eastern sea routes. Alternative routing strategies can distribute cargo more evenly across ports and reduce pressure on specific corridors.
- Enhance vessel scheduling coordination to avoid congestion peaks. Improved scheduling can ensure better spacing of vessel arrivals, thereby reducing port overcrowding.
- Implement digital tracking and real-time visibility systems. This would improve transparency and enable better decision-making by providing accurate updates on cargo movement.
- Strengthen multimodal connectivity and logistics infrastructure. Improved connectivity between ports and inland transport networks can reduce delays beyond the port environment.

- Develop alternative ports to distribute cargo load more evenly. Encouraging the use of less congested ports can help balance traffic and improve overall system efficiency.

VII. CONCLUSION

The study establishes that port dwell time delays are a persistent and structural characteristic of Indian import logistics rather than isolated operational disruptions. The analysis clearly shows that port congestion is a major contributing factor, with a majority of respondents consistently experiencing high levels of congestion affecting clearance timelines. This indicates that delays are embedded within the system and are influenced by infrastructural limitations, procedural inefficiencies, and coordination challenges across multiple stakeholders.

A key outcome of the study is the identification of a strong relationship between dwell time delays and import lead time volatility. The findings reveal that logistics professionals face significant difficulty in predicting delivery timelines, reflecting a high degree of uncertainty in shipment planning. This unpredictability disrupts supply chain efficiency and limits the ability of firms to operate with precision, thereby reinforcing the importance of addressing dwell time as a critical determinant of logistics performance.

The study also highlights the substantial financial impact of dwell time delays, particularly in the form of demurrage, detention, and additional logistics costs. The concentration of responses in higher impact categories confirms that these costs are not occasional but form a recurring burden for importers. This not only increases operational expenses but also compels firms to adopt compensatory strategies such as maintaining higher inventory levels and allocating additional resources for contingency planning.

Finally, the study brings attention to the role of eastern sea route dependency in influencing port congestion patterns. The findings suggest that concentration of cargo through specific maritime routes contributes to increased operational pressure on certain ports, thereby affecting dwell time behaviour. Overall, the study concludes that addressing port dwell time delays requires a comprehensive approach involving technological integration, infrastructure development, policy reforms, and improved coordination among stakeholders. Effective implementation of these measures can significantly enhance supply chain reliability, reduce lead time variability, and improve the overall efficiency of India's import logistics system.

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