Lead Time Analysis in Port-To-Plant Material Movement and its Impact on Supply Chain Performance At Chennai Port Authority

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ABSTRACT

Lead time is a critical factor influencing supply chain efficiency, particularly in port-based logistics systems. This study examines lead time variability in port-to-plant material movement and its impact on supply chain performance at Chennai Port Authority. A descriptive research design was adopted using both primary and secondary data. Primary data was collected from 70 respondents, including logistics professionals and port employees, through structured questionnaires.

The findings reveal that transportation delays, customs procedures, and infrastructure limitations significantly affect lead time. The study also highlights the role of digital technologies such as automation and real-time tracking in improving efficiency. It concludes that enhancing infrastructure, simplifying processes, and adopting digital solutions can reduce delays and improve supply chain performance.

Keywords: Lead Time, Supply Chain, Port Logistics, Transportation Delays, Digital Transformation

INTRODUCTION

Efficient supply chain management is essential for ensuring smooth production and distribution. Lead time, defined as the total time taken for materials to move from port to plant, plays a vital role in determining operational performance.

Chennai Port Authority is a key hub for trade supporting multiple industries. However, issues such as transportation delays, port congestion, and customs procedures often increase lead time, leading to higher costs and reduced efficiency. This study aims to analyze factors affecting lead time and their impact on supply chain performance.

Supply chains depend on predictable material flows, and lead time is one of the most important performance indicators in logistics management. Lead time refers to the total elapsed time between the arrival of cargo at the port and its availability at the manufacturing plant. When lead time increases, organizations face higher

inventory carrying costs, production interruptions, customer dissatisfaction, and reduced competitiveness. Therefore, controlling lead time is central to lean and agile supply chain systems.

Chennai Port Authority is one of India's strategically important maritime gateways serving automotive, engineering, petroleum, and manufacturing sectors. The port connects import cargo with inland plants through road and rail networks. However, congestion, gate delays, vessel bunching, documentation checks, customs clearance procedures, and limited hinterland connectivity can lengthen cargo movement cycles. These issues create uncertainty for production planners and procurement teams.

Prior studies indicate that integrated logistics planning, digital visibility tools, and collaborative governance models can improve turnaround time and reliability. Christopher (2018) emphasized time-based competition as a source of strategic advantage, while Notteboom (2019) linked port-hinterland connectivity with logistics performance. In the Indian context, the National Logistics Policy highlights multimodal integration and process simplification as major priorities.

This study focuses on measuring the operational causes of lead time variation in port-to-plant movement and evaluating their influence on supply chain performance at Chennai Port Authority. The findings can support managers in improving planning accuracy, reducing avoidable delays, and strengthening end-to-end coordination among port, transporters, customs, and manufacturing units.

REVIEW OF LITERATURE

Christopher (2018) explained that time-based competition helps firms gain advantage through faster response systems. Chopra and Meindl (2019) noted that lead time variability increases safety stock and inventory cost. Rodrigue (2019) emphasized that transport network efficiency determines cargo flow reliability. Notteboom (2019) reported that strong port-hinterland connectivity improves logistics performance and reduces inland delays.

Bowersox, Closs and Cooper (2020) stressed the importance of integrated logistics information systems for coordination. Russell, Ruamsook and Thomchick (2020) found that capacity constraints at ports increase uncertainty and delay risk. Govindan and Bouzon (2020) highlighted resilience strategies to absorb disruptions in supply chains. Gunasekaran et al. (2021) argued that analytics-based performance measures support better logistics decisions.

UNCTAD (2022) identified trade facilitation and customs modernization as major drivers of port efficiency. Ahmed, Khan and Ali (2022) found that real-time optimization tools improve scheduling and berth planning. Lee and Park (2023) showed that digital twin technology enhances visibility and scenario analysis. World Bank (2023) stated that predictable clearance processes improve national trade competitiveness.

Kumar, Singh and Verma (2024) demonstrated that machine learning models can accurately predict travel time and delays. Sharma and Gupta (2024) linked congestion with lower port productivity and longer dwell time. Fiberesima and Gabriel (2025) concluded that digitalization significantly reduces seaport lead time. These studies collectively indicate that technology, infrastructure, and coordination are central to lead time reduction.

RESEARCH METHODOLOGY

The study adopted a descriptive research design because it enables systematic examination of operational factors affecting lead time. Both quantitative and qualitative perspectives were considered to understand the relationship between delays and supply chain outcomes.

Primary data was collected through a structured questionnaire administered to 70 respondents consisting of logistics executives, transport coordinators, customs intermediaries, warehouse staff, and port-related employees. Secondary data was gathered from journals, books, policy reports, and industry publications.

Convenience sampling was used due to respondent accessibility within operational locations. The questionnaire contained demographic items, Likert-scale measures on delay causes, and performance-related perceptions. A pilot review was undertaken to improve clarity of questions.

Data analysis employed percentage analysis for profiling responses, Chi-square test for association between categorical variables, One-Way ANOVA for difference in perceptions across experience groups, and correlation analysis to examine the relationship between lead time and supply chain performance.

ANALYSIS AND DISCUSSION

Chi-square Test

Variable	χ^2 Value	p-value	Result
Transportation Delay vs Operational Cost	10.52	<0.05	Significant

The Chi-square result indicates a statistically significant association between transportation delays and operational cost. When delays rise, organizations incur higher demurrage, detention, overtime, and rescheduling expenses. Hence, the null hypothesis is rejected. Reducing transit bottlenecks can directly lower avoidable logistics costs and improve budget control.

One-Way ANOVA

Factor	F Value	p-value	Result
Experience vs Delay Perception	1.84	>0.05	Not Significant

The ANOVA outcome shows no significant difference in perceptions across experience levels. Employees with different years of service broadly agree on the causes of delays. This consistency suggests that operational issues are visible across the organization rather than limited to a single employee group.

Correlation Analysis

Variables	Correlation (r)	p-value	Result
Lead Time vs Supply Chain Performance	-0.032	>0.05	Not Significant

The correlation value indicates a weak negative relationship between lead time and supply chain performance. As lead time increases, performance tends to decline through slower replenishment and lower responsiveness.

Although statistically weak in this sample, the directional effect aligns with logistics theory and supports continued focus on lead time reduction.

CONCLUSION

The study highlights the importance of managing lead time in port-to-plant logistics. Transportation delays, infrastructure limitations, and procedural inefficiencies are key contributors to increased lead time. Improving infrastructure and adopting digital technologies can significantly enhance supply chain performance. Strengthening coordination among stakeholders will further reduce delays and improve efficiency.
The study also confirms that lead time management is a decisive element in efficient port-to-plant logistics. Transportation delays, congestion, documentation procedures, and infrastructure constraints remain key contributors to variability in cargo movement. Such variability can increase cost, disrupt production schedules, and weaken service levels.

Improvement requires a combined strategy involving infrastructure upgrades, process simplification, real-time tracking, data sharing, and stronger coordination among stakeholders. Chennai Port Authority and connected

industries can achieve better supply chain performance by treating lead time reduction as a continuous improvement priority.

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