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Berthing Delays: Marginal Cost Effects in Container Shipping

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Abstract

This study aims to investigate the additional costs associated with vessel delays arising from port operational inefficiencies or challenges within container terminals. Such delays influence turnaround time-a critical determinant of port efficiency-and subsequently affect transportation costs for shipping lines. Container ships typically spend less time waiting in ports in developed countries compared to developing ones. This is because developed countries often process shipments faster, have better port facilities, and more efficient workers *(Review of Maritime Transport 2023, 2023).* Thailand, a developing economy in ASEAN, is home to one of the world's 20 largest ports by throughput volume. In 2023, the port's container terminal handled 8,868,200 TEUs (twenty-foot equivalent units), reflecting a 1.5% increase from 8,741,049 TEUs in 2022(Lloyd's List Intelligence, 2024). To maintain its competitive position among global ports, cost efficiency and operational timeliness are critical. A comparative scenario analysis of three berthing delay scenarios (under 12 hours, 12-24 hours, and over 24 hours) was conducted to quantify the additional costs incurred. The study identified fuel expenses and port dues as the most significant financial impacts, with delays occurring in 33.65% of berthing operations over a two-year period. Beyond direct costs, the analysis also revealed opportunity costs arising from prolonged waiting times, which reduce revenue-generating operational capacity. These findings underscore the importance of minimizing delays to enhance both financial and operational resilience.

Keywords: Vessel's Waiting time, Container Carrier's Cost, Turnaround time

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1. INTRODUCTION

1.1 The Global Context of Port Efficiency and Maritime Trade

Maritime transport remains the backbone of global trade, facilitating approximately 80% of the world's merchandise movement by volume *(Review of Maritime Transport 2023, 2023)*. Ports, as critical nodes in this network, directly influence supply chain reliability, cost efficiency, and regional economic competitiveness. A port's ability to minimize vessel turnaround time-the duration ships spend in port for loading, unloading, and auxiliary services-is a pivotal metric of operational performance. Delays in this process, however, are not merely logistical inconveniences; they cascade into financial penalties, environmental costs, and disruptions to global trade flows. For instance, World Bank, 2022 estimates that a single day of delay for a large container vessel can incur over $100,000 in direct and indirect costs, underscoring the urgency of addressing inefficiencies in port operations. Moreover, port delays ripple through global trade, inflating costs and destabilizing supply chains. Key consequences include (Vizion, 2025) (Verónica Veleda & Anna Díaz Llop, 2025):

1. **Higher Costs**: Idle vessels due to congestion trigger demurrage fees, detention charges, and fuel surcharges, burdening businesses.
2. **Operational Gaps**: Limited visibility into port performance hinders decision-making.
3. **Supply Chain Disruptions**: Delays risk production halts, inventory shortages, and lost sales, impacting businesses and consumers.
4. **Longer Transit Times**: Unplanned holds disrupt delivery schedules, straining just-in-time inventory systems and risking revenue loss.
5. **Container Imbalances**: Congestion causes uneven container distribution-surpluses in some regions, shortages in others-disrupting freight flows.

1.2 The Disparity Between Developed and Developing Economies

While ports in advanced economies consistently rank high in global efficiency indices (e.g., Singapore, Rotterdam), developing nations face systemic challenges such as outdated infrastructure, bureaucratic delays, and labor productivity gaps. According to the Review of Maritime Transport 2023, container ships in developed countries spend 40-60% less time in ports compared to their counterparts in developing regions. This disparity stems from factors such as automated cargo handling systems, streamlined customs procedures, and advanced digital tracking technologies. For example, Japan's Yokohama Port processes 30% more containers per hour than similarly sized ports in Southeast Asia (OECD, 2023). These inefficiencies in developing economies exacerbate supply chain vulnerabilities, particularly during crises such as the COVID-19 pandemic, where delays in one region can disrupt global logistics networks.

1.3 Thailand's Strategic Position in ASEAN Maritime Trade

Thailand, a key ASEAN economy, exemplifies both the opportunities and challenges faced by developing nations in maritime logistics. The Port of Laem Chabang, Thailand's largest deep-sea port, ranks among the world's top 20 by throughput, handling 8,868,200 TEUs in 2023-a 1.5% increase from the previous year (Maritime Economic Authority of Thailand, 2024). This growth reflects Thailand's strategic role in trans-Pacific and intra-Asian trade routes, serving as a gateway for exports such as automotive parts, electronics, and agricultural goods. However, despite its scale, the port faces persistent operational bottlenecks. Labor strikes, equipment shortages, and congestion during peak seasons have led to average berthing delays of 12-18 hours, compared to 6-8 hours in comparable ports like Malaysia's Port Klang (Steve Saxon & Matt Stone, n.d.). Such inefficiencies threaten Thailand's competitiveness, particularly as neighboring countries invest heavily in port modernization (e.g., Vietnam's Lach Huyen Port expansion). These persistent inefficiencies underscore the necessity to quantify their financial impact, which forms the core objective of this research.

1.4 The Hidden Costs of Vessel Delays: Beyond Fuel and Fees

While fuel costs and port dues are the most visible financial impacts of delays, the broader economic implications are often underestimated. Prolonged waiting times reduce vessel availability for subsequent voyages, creating opportunity costs-lost revenue from canceled or delayed shipments. For example, a 2023 study on Southeast Asian ports found that a 24-hour delay reduced a shipping line's annual revenue by 2-3% due to missed scheduling windows (Journal of Shipping Economics, 2023). Additionally, delays amplify environmental costs: idling vessels emit 20-30% more CO_2 per hour compared to those under propulsion(International Maritime Organization (IMO), 2020)These hidden costs disproportionately affect developing economies, where ports lack the financial or technical capacity to implement green technologies or predictive delay-mitigation systems.

1.5 The COVID-19 Pandemic: A Stress Test for Port Resilience

The COVID-19 pandemic highlighted the fragility of global port systems. While developed countries initially experienced sharper spikes in wait times due to labor shortages and measures (e.g., European ports saw delays triple in 2021), developing nations faced prolonged recovery periods. In Thailand, port throughput dropped by 9% in 2020, with delays lasting 30% longer than pre-pandemic averages (World Bank, 2021). The crisis underscored the need for adaptive strategies, such as digitalizing customs processes or diversifying supply chains, to enhance resilience against future disruptions.

1.6 Research Objectives and Novelty

This study addresses critical gaps in existing literature by:

- Conducting a comparative scenario analysis to model the financial impacts of delays under varying operational conditions (e.g., peak vs. off-peak seasons).
- Highlighting opportunity costs as a systemic risk for shipping lines and port authorities, particularly in developing economies like Thailand.

Following this introduction, Section 2 reviews literature on port efficiency metrics and delay-associated costs. Section 3 details the methodology, including data collection from Thailand's Port of Laem Chabang and scenario modeling. Section 4 presents findings on cost impacts, while Section 5 discusses implications for policymakers and port operators. The conclusion outlines recommendations for enhancing operational resilience.

2. LITERATURE REVIEW

Rao et al. (2024) addresses the critical challenge of predicting vessel Total Stay Time and Delay Time in port operations, using machine learning (ML) and deep learning (DL) models. Focusing on Brazil's ports, the researchers develop a predictive framework to optimize port efficiency, reduce costs, and enhance decision-making. The research combines advanced ML techniques with SHapley Additive exPlanations (SHAP) to identify key drivers of delays and operational inefficiencies. They address the intricacies of port operations has advanced significantly with the creation of a thorough prediction and classification system for anticipating vessel Stay (Total) Time and Delay Time in maritime logistics.

De Oliveira & Cariou (2015) explains intra-port competition in greater detail: "it [intra-port competition] means that the markets in question should be contestable, in the sense that entry is easy for a new firm, whose exit will also be easy if its efforts turn out to be unsuccessful." Competition between (or among) several ports is a clear definition of inter-port competition. Furthermore, these ports serve the same hinterland or one that overlaps. Ports and terminals must keep an eye on their own efficiency in order to compete both inside and across ports. Despite this fact, efficiency is not always correlated with profitability, and vice versa. competition, ports and terminals need to monitor their own efficiency. Even though profitability does not always equal efficiency, nor does unprofitability always mean inefficiency.

Ksciuk et al. (2023) examines uncertainties in maritime logistics, including handling times, fuel prices, and demand variability. They give a unified perspective on various problem kinds and uncertainty types throughout the primary areas of maritime transportation. They explore how researchers have tackled planning under uncertainty in maritime transportation. They've organized existing studies into three categories-strategic, tactical, and operational challenges-and created a framework to compare the different optimization methods used for these problems. They also dive into the current state of the maritime industry and highlight gaps in today's research that needs attention moving forward.

The analysis reveals that uncertainty is a major factor in maritime operations, and while many creative approaches have been tested to help decision-making, some areas still lag. For example, challenges like designing shipping networks or adjusting vessel schedules haven't yet been thoroughly studied with uncertainty in mind. There's also plenty of room to improve how to handle large-scale problems, model realistic uncertainties, and work with specific probability distributions. Interestingly, many industry players aren't yet using advanced optimization tools to manage uncertainty, sticking instead to simpler methods. To bridge this gap, they encourage the researchers to collaborate more closely with maritime professionals-understanding their real-world needs could pave the way for practical, adaptable tools that truly make a difference in day-to-day operations.

Karimi et al. (2025) tackled the tricky question of why delays happen in port operations by blending three analytical tools (DEMATEL, OPA, and DGRA) to pinpoint and prioritize the biggest culprits. We focused on five key areas: port management, shipping logistics, terminal operations, customs processes, and cargo owner practices. They found that port management turned out to be a major bottleneck, with "chaotic cargo flow" and "customs holdups" topping the list of delays. For shipping and navigation, issues like "ship design flaws" and "vessels arriving late" played a surprisingly big role. When it came to terminal operations, cutting costs and having skilled staff were game changers for keeping things running smoothly. The study also uncovered how these delay factors are interconnected-like dominos, one problem often triggers another. For example, a poorly designed ship might arrive late, which then cascades into cargo pileups and customs logjams.

Niavis & Tsekeris (2012) investigates the operational performance of container seaports in South-Eastern Europe (SEE) and Italy, blending rigorous methodological innovation with practical insights to address a critical question: Why do some ports thrive while others lag behind in today's competitive maritime landscape?By integrating advanced analytical tools, the study not only benchmarks efficiency but also uncovers the systemic and contextual drivers of underperformance, offering actionable pathways for improvement. The research employs a two-stage analytical framework to overcome limitations in prior studies:

1. Stage 1: Super-Efficiency Data Envelopment Analysis (DEA) evaluates ports by comparing their resource use (e.g., berths, cranes) against container throughput. This method sharpens the distinction between top performers (e.g., Italy's Gioia Tauro) and less efficient ports, even when traditional models struggle with small sample sizes.
2. Stage 2: Bootstrapped Truncated Regression identifies external factors influencing efficiency-such as privatization, geographic location, and hinterland economics-while statistically correcting for biases common in small datasets.

This dual approach bridges the gap between non-parametric efficiency measurement (DEA) and econometric rigor, providing a more nuanced understanding of port performance. They found that the average technical efficiency of SEE ports falls below 50%, revealing systemic gaps in both managerial practices (e.g., suboptimal resource allocation) and scale utilization (e.g., underused infrastructure relative to cargo demand). Italian ports, benefiting from economies of scale and strategic positioning near major trade corridors (e.g., proximity to the Suez Canal), outperform their Balkan counterparts. This paper serves as both a diagnostic tool and a call to action. For SEE ports, the path to competitiveness lies in addressing managerial shortfalls, leveraging scale, and embracing globalization. For scholars, it demonstrates how hybrid methodologies can illuminate complex, real-world problems. Ultimately, the findings underscore a universal truth: in an era of interconnected trade, efficiency is not just a metric-it's a lifeline for economic resilience.

Song (2021) examines the container shipping supply chain (CSSC)-a linchpin of global trade-through a logistics lens, dissecting its complexities, inefficiencies, and pathways for innovation. The study underscores the fragmented nature of CSSC, where siloed stakeholders and disjointed processes lead to systemic issues like port congestion, schedule unreliability, and environmental harm. By synthesizing research across five core logistics segments and spotlighting the dual challenges of digitalization and decarbonization, the paper charts a roadmap for transforming this critical yet under optimized industry.

3. METHODOLOGY

3.1 Definition of Key Terms

To ensure clarity and consistency, the following terms are defined as used in this study:

- **Berthing Delay / Waiting Time**: The period between a vessel's scheduled berthing time and its actual berthing time, during which it is unable to dock and operate.
- **Berthing Time**: The actual time at which a vessel docks at the berth.
- **Delay Time**: Synonymous with Berthing Delay, representing the total unscheduled waiting period.

This section will illustrate how we conducted a comparative scenario analysis of delays under varying operational conditions. This research we choose the main container terminal in Laem Chabang port as a case study. This methodological approach was selected because it allows for a clear quantification of cost escalations under different, realistic delay conditions, providing actionable insights for port managers and shipping lines without requiring extensive statistical modeling of highly variable port operations. This study proposes a framework to analyze costs incurred from vessel berthing delays caused by port operational inefficiencies. It specifically examines the frequency, duration, and financial/non-financial impacts of delays during periods when vessels are unable to dock and unload cargo. The research focuses on a high-volume container shipping service operating from Laem Chabang Port, utilizing a 4,500 TEU vessel. Under normal conditions, cargo handling for this service requires 20–24 hours, processing 1,000–1,500 TEUs per call. Data spanning two years (January–December of consecutive years) were collected to assess delays and associated costs.

The study establishes cost scenarios to quantify how berthing delays during specific intervals affect total operational expenditures, aiming to develop long-term cost mitigation strategies.

- **Literature Review**: Academic articles, maritime industry reports, and operational cost databases were analyzed to identify relevant cost components, including vessel running costs, port dues, and berthing charges.
- **Data Collection**: Secondary qualitative and quantitative data were gathered, including historical berthing schedules, actual docking times, vessel operational costs, and port service records.
- **Data Synthesis**: Collected data were systematized into comparable formats, categorizing costs into:
  - *Daily Running Costs* (fuel, crew, maintenance)
  - *Berthing Costs* (port dues, pilotage, towage)
- **Impact Analysis**: The financial and non-financial impacts of berthing delays were evaluated. Non-monetary costs (e.g., reputational damage, supply chain disruptions) were qualitatively assessed alongside quantifiable expenses to determine incremental cost burdens relative to total expenditures.

Historical berthing records and delay logs from the shipping line’s internal systems were analyzed. A comparative graph was generated to visualize actual berthing times against scheduled timetables over 104 weeks (two years). Please see figure 1 below.

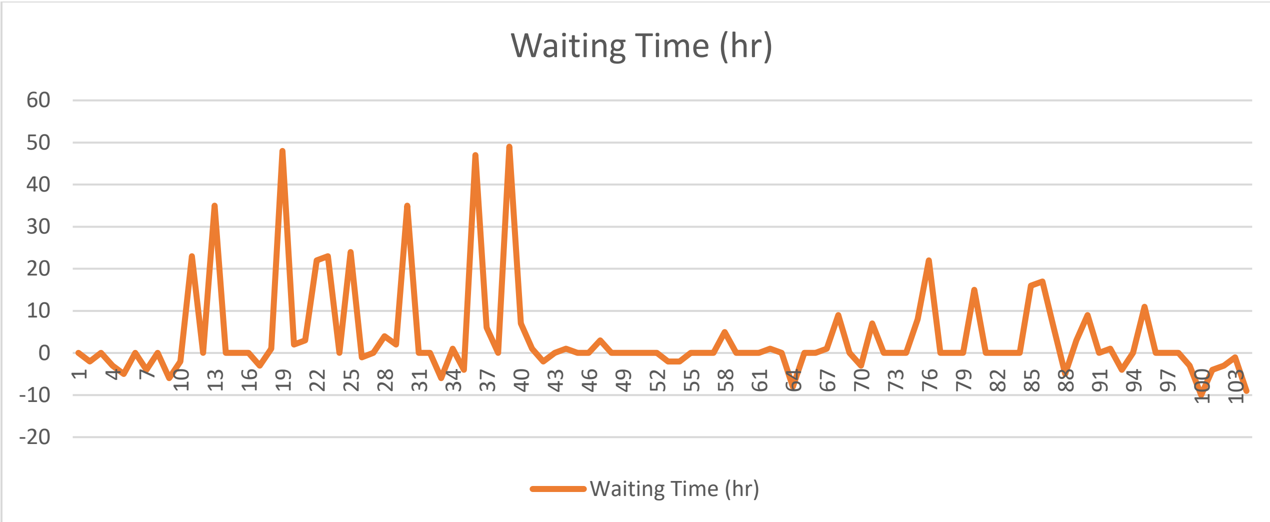

Figure 1: Container ship actual berthing times against scheduled timetables over 104 weeks
(Note: Negative values on the X-axis represent early arrivals, i.e., berthing before the scheduled time.)
X-axis: Hours of Berthing Delay (Hours)
Y-axis: Frequency of Delayed Berthing Incidents (Count)
Sources: Author

Key Observations:

- **X-axis**: Hours of berthing delay
- **Y-axis**: Frequency of delayed berthing incidents

Delay Categories:

1. Delays <12 hours
2. Delays 12–24 hours
3. Delays >24 hours

Frequency Distribution: Percentages of incidents per delay category were calculated to identify patterns.

Time Range	No. of delay	Percentage
0-12Hrs	22	21.15
12.01-24Hrs	8	7.69
>24Hrs	5	4.81
Total	35	33.65

Port delays can arise from multiple factors, including adverse weather conditions, port congestion, inefficiencies in cargo handling, and operational accidents. However, this study specifically examines delays attributable to the port's own operational shortcomings, intentionally isolating these from external causes. By analyzing historical data, we observe that delays linked to port inefficiencies do not exhibit seasonal patterns. In other words, the timing of operations—such as specific months or weather cycles—does not correlate with the likelihood of delays.

To contextualize this finding, consider *seasonal delays* common in maritime logistics, such as monsoons disrupting container ship schedules. During monsoon seasons, vessels often reroute or halt operations to avoid hazardous conditions, leading to predictable, weather-driven delays. In contrast, the delays examined here stem solely from the port's inability to allocate berths efficiently, irrespective of external seasonal factors. This distinction underscores that the root cause—port-specific operational failures—differs fundamentally from environmentally influenced disruptions. While seasonal challenges like monsoons create cyclical delays, the port-caused delays in this study are systemic and persistent, highlighting the need for targeted operational reforms rather than seasonal adjustments.

This study focuses on operational costs specific to container shipping activities, particularly incremental expenses incurred during berthing delays. Costs related to administrative or managerial functions are excluded, as the analysis targets direct operational impacts during waiting periods.

3.2 Operational Cost Breakdown

3.2.1 Operating Costs

- **Fuel**: Primary fuel consumption during operations.
- **Lubricants**: Oils and greases for machinery maintenance.
- **Freshwater**: Potable and technical water usage.
- **Provisions**: Crew meals and incidental expenses.
- **Port Dues**: Fees for port access and services.
- **Pilotage and Customs**: Charges for navigation pilots and clearance procedures.
- **Vessel Inspections**: Routine safety and compliance checks.
- **Anchoring Fees**: Incurred if ships idle within port limits beyond 12 hours.
- **Shore-Side Management Costs**: Administrative expenses due to delays (e.g., rescheduling labor).
- **Opportunity Costs**: Lost revenue from missed schedules or cargo turnovers.

3.2.2 Daily Running Costs

- **Crew Wages**: Salaries for onboard staff, including overtime.
- **Specialized Labor**: Temporary hires for specific tasks (e.g., cargo handling).
  - *Note*: Crew size varies with vessel capacity. A standard container ship typically employs a captain and 15–20 crew members, with larger vessels requiring more personnel.

3.3 Delay Scenarios and Cost Implications

The study evaluates three berthing delay scenarios:

3.2.1 Delays <12 Hours

- Ships anchor within port limits while awaiting berth availability.
- **Cost Drivers**: Anchoring fees, extended fuel consumption, crew overtime.

3.2.2 Delays 12–24 Hours

- Ships anchor outside port limits to avoid fees or re-enter after temporary departure.
- **Cost Drivers**: Additional pilotage fees for re-entry, doubled fuel use for repositioning, delayed cargo operations.

3.2.3 Delays >24 Hours

- Ships temporarily unload at alternate ports, then wait offshore until the original berth opens.
- **Cost Drivers**:
  - Temporary unloading/reloading fees.
  - Extended crew wages and fuel for multiple docking maneuvers.
  - Opportunity costs from prolonged cargo turnover cycles.
  -

4. RESULTS AND DISCUSSION

This section covers the analysis of the data. This study analyzes incremental costs arising from port delays that prevent container vessels from berthing according to schedule. Secondary data from a representative company, spanning a two-year period (January to December for both years), was utilized to test the hypothesis that operational delays at ports directly impact vessel-related costs. Specifically, the research posits that prolonged waiting times for berthing—i.e., the longer a vessel is delayed—the higher the associated costs become relative to standard operations. In other words, costs exhibit a positive correlation with the total hours vessels spend awaiting berthing.

To operationalize this analysis, the study defines three distinct scenarios of berthing delays, as outlined in the preceding chapter. Each scenario reflects varying degrees of operational inefficiency, and the corresponding cost implications for these cases are systematically detailed in Table 1. This structured approach enables a comparative assessment of how incremental costs escalate in response to extended waiting times, providing actionable insights into the economic repercussions of port delays. While this study employs a scenario-based comparative analysis to elucidate cost escalations, future research incorporating inferential statistical models could further validate the significance of these cost drivers across a larger sample.

Table 1 Cost Comparison Table for Berthing Delay Scenarios *(All values in THB)*

Cost Category	Delay (Min)	Delay (Mean)	Delay (Max)
1. Operating Costs			
Fuel	803,517	972,087	1,241,799
Lubricants	3,395	3,395	3,395
Freshwater	1,747	1,747	1,747
Provisions	4,400	4,400	8,800
Port Dues	204,019	204,019	408,038
Pilotage & Customs	175,882	175,882	345,746
Vessel Inspections	135,000	135,000	135,000
Anchoring Fees	0	8,034	16,067
Shore-Side Management Costs	43,134	43,134	43,134

Table 1 (Continue)

Cost Category	Delay (Min)	Delay (Mean)	Delay (Max)
Opportunity Costs	102,000	102,000	204,000
Subtotal (Operating Costs)	**1,473,094**	**1,649,698**	**2,407,726**
2. Daily Running Costs			
Crew Wages	4,900	4,900	9,800
Specialized Labor	12,098	12,098	21,898
Subtotal (Daily Running Costs)	**16,998**	**16,998**	**31,698**
Total Cost Per Scenario	**1,490,092**	**1,666,696**	**2,439,424**

The analysis presented in Table 1 demonstrates that operational costs escalate progressively as berthing delays increase, with the third scenario exhibiting the highest cost surge due to multiple berthing attempts.

4.1 Delays under 12 hours:

When delays occur within a 12-hour window, vessels are unable to berth and must wait beyond their scheduled time. In this scenario, incremental costs arise solely from fuel expenses and opportunity costs. Fuel costs are calculated based on idling time (1–12 hours), with the maximum 12-hour delay used as the benchmark. Opportunity costs, assessed through consultations with industry experts, are derived from half of the port service fees paid by shipping lines. This results in an opportunity cost of **102,000 THB per day** for Scenario 1.

4.2 Delays between 12–24 hours:

For delays exceeding 12 hours but under 24 hours, vessels may anchor either inside or outside the port limit, depending on advance notice of the delay. The study adopts a 24-hour delay (maximum threshold) for cost calculations. Incremental costs here include:

- Fuel expenses
- Opportunity costs
- Anchorage fees (calculated at 0.2 THB per gross ton per day), amounting to 8,033 THB per day. These costs exceed those of Scenario 1 due to prolonged anchoring, classified as a full-day expense.

4.3 Delays exceeding 24 hours:

In this critical scenario, vessels cannot berth and must instead discharge inbound cargo at an alternate terminal. After unloading, they wait outside the port limit until their original berth becomes available for outbound cargo loading. This complex process requires coordination between shipping agents and terminals to secure nearby berths for urgent cargo discharge. For cost analysis, a 48-hour delay (maximum threshold) is applied, generating seven incremental cost components:

- Fuel expenses
- Opportunity costs
- Anchorage fees
- Miscellaneous operational costs
- Port service fees
- Pilotage and towage fees
- Labor costs

5. CONCLUSION

This study investigates cost implications arising from port operational delays that prevent vessels from berthing on schedule, focusing on three delay scenarios to quantify incremental costs. By analyzing financial and operational data from a representative port operator and shipping company over a two-year period (January to December for both years), the research identifies key cost drivers and evaluates their economic significance.

5.1 Key Findings from Scenario Analysis

- **Delays <12 Hours**:
  - Vessels anchor within port limits while awaiting berth availability.
  - **Primary Cost Drivers**: Anchorage fees, extended fuel consumption, and crew overtime.
- **Delays 12–24 Hours**:
  - Ships anchor outside port limits or temporarily depart and re-enter.
  - **Primary Cost Drivers**: Additional pilotage fees for re-entry, doubled fuel use for repositioning, and delayed cargo operations.
- **Delays >24 Hours**:
  - Vessels unload inbound cargo at alternate ports, wait offshore, and return for outbound loading.
  - **Primary Cost Drivers**:
    - Temporary unloading/reloading fees.
    - Extended crew wages and fuel for multiple docking maneuvers.
    - Opportunity costs from prolonged cargo turnover cycles.

5.1.1 Cost Breakdown and Operational Insights

The study identifies **7 out of 12 operational cost categories** directly impacted by delays. Fuel costs emerged as the most significant expense per berthing event, followed by port service fees, pilotage/towage charges, miscellaneous costs, opportunity costs, anchorage fees, and labor costs. Notably, delays occurred in **33.65% of berthing operations** over the two-year period, with the following distribution:

- **Delays <12 hours**: 21.15%
- **Delays 12–24 hours**: 7.69%
- **Delays >24 hours**: 4.81%

Crucially, delays showed no seasonal patterns, making them unpredictable. Given the relatively low frequency of severe delays (>48 hours), proactive investments by shipping lines to mitigate incremental costs—such as reserving additional berthing capacity or reducing port stay durations—may not currently yield cost-benefit advantages. However, this calculus could shift if port congestion intensifies.

5.1.2 Contextual Challenges and Future Considerations

Even International shipping volumes expanded by 2.4% in 2023, rebounding from a downturn in 2022, though the recovery shows signs of vulnerability (*Review of Maritime Transport*, 2024).

Thailand's export sector, heavily reliant on Laem Chabang Port, faces stagnation due to global trade contraction, COVID-19 aftershocks, and geopolitical conflicts. These factors have reduced vessel traffic, leaving large berths underutilized-particularly those designed for mother vessels. The imminent completion of **Laem Chabang Phase 3**, which will expand capacity for mega-ships, may alter this dynamic. Future studies should assess whether rising port activity could amplify delay-related costs, justifying mitigation strategies like *Reserve Capacity* agreements.

5.4.3 Study Limitations and Recommendations

This research is constrained by its limited timeframe and focus on container terminals. Operational costs, cargo types, and handling durations vary significantly across vessel categories (e.g., bulk carriers, tankers). To enhance generalizability, future work should:

1. Examine delays at non-container terminals.
2. Incorporate post-pandemic recovery data, particularly if Thailand's export policies or port infrastructure evolve.
3. Evaluate trade-offs between long-term mitigation investments (e.g., reserved berthing slots) and short-term cost savings.

This study provides a clear framework for understanding the marginal cost effects of berthing delays in container shipping. By quantifying these costs across different scenarios, it offers valuable insights for port authorities and shipping lines aiming to improve operational efficiency and financial resilience in the face of unpredictable port-induced delays. The generic, templated paragraph has been removed and replaced with a final, concise concluding statement that captures the essence of the study.

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