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The Consequences of Container Vessel Collisions with Quay Cranes: A Case Study

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Abstract

In the last few years, several container terminals have faced accidents of collision between vessels and ship-to-shore (STS) gantry cranes, causing damage and losses to the Port and terminal. The notion of port management should be designated to oversee the increasing amount of containers, particularly in the event of accidents or emergencies.

The primary research gap is that the majority of current literature predominantly depends on simulations, leading to a lack of empirical data. Accordingly, this article analyzes the impact and consequences of the collision involving an 8,000+ TEU container vessel and two Post-Panamax gantry cranes on container terminal operations, productivity, and related financial costs and losses, assigning empirical data. The study employs quantitative methods using port performance indicators (PPIs), which are well-established in maritime literature for measuring terminal efficiency, to quantify the impact of container ship STS gantry crane collisions at a container terminal. Pre- and post-incident PPIs show how the collision affected productivity, resource distribution, and service standards. Losses are assessed using financial indicators. The accident results revealed an increase in the Berth Occupancy Rate from 24% to 43%, a 40% rise in ship turnaround time, an increase in waiting time, a drop in the number of vessels, and a financial loss.

The research contributes to providing PPI-based empirical quantification of STS collision impacts based on PPI, facilitating a better understanding of how vessel and STS incidents influence terminal production and performance using actual data. The study employs PPIs as measures of time, ship, STS, and financial loss to assess terminal disruption.

Keywords:
Container terminals, STS gantry cranes, Port management, Port performance indicators.

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1. Introduction

Transportation of goods and people is the core role of the maritime industry. Seaboard trade in 2019 is 11.08 billion tons, 2020 is 10.65 billion tons, 2021 is 12.027 billion tons, and in 2024 it reaches 12.720 billion tons, rising from 7.8 billion tons in the 2008 financial crisis. UNCTAD projects a moderate and steady growth in seaborne trade volume for the medium term between 2024 and 2028, indicative of the sector's resiliency (UNCTAD, 2019, 2020, 2021, 2023, 2024, 2025).

Containerized cargo globally had a substantial increase exceeding 6%. Attained second position in several categories of products in 2024 (UNCTAD, 2025). Container terminals serve as a primary hub in the expansion of international trade. Terminals should adapt containers to increase volume regardless of their spatial constraints (Zaerpour et al., 2019). Container terminals should serve huge vessels efficiently with minimum time and competitive rates. Accordingly, terminal operators, port authorities, and shipping lines should allocate resources towards advanced technologies to enhance infrastructure and operating efficiency (Gharehgozli et al., 2014)

To uphold secrecy and safeguard the reputation of the container terminal and the shipping line pertinent to this research, the terminal was designated as "Terminal X" and the vessel as "CONT Z". While maneuvering CONT Z to the berth at Terminal X, assisted by two tugboats, CONT Z collided with the starboard bow with two gantry cranes at Terminal X, resulting in significant damage to both cranes.

This research objective is to examine the effects and ramifications of the collision between an 8,000+ TEU container carrier and two Post-Panamax gantry cranes concerning terminal productivity and associated financial expenses and losses. The research questions are: what are the operational and productive consequences of the accident? What are the expected financial losses as a consequence of the accident?

2. Background

Container terminals manage global containerized trade volumes, which saw robust growth in 2024, with an increase of 6%, totaling over 170 million twenty-foot equivalent units (TEUs) (UNCTAD, 2025). Ship-to-shore (STS) gantry cranes are crucial for the efficient operation of ports as they facilitate the handling of containers between the quay and the vessel. Accordingly, accidents of STSs cause terminal operational disturbance.

PPIs assess efficiency using throughput (TEUs/hour), cycle time (minutes per move), berth utilization (%), and energy consumption (kWh/TEU). UNCTAD in 2012 suggested indicators as dwell time and crane productivity, where Crane dormancy leads to instantaneous and prolonged interruption. Recently, ports were ranked by the container performance index (CPPI), assigning AIS data regarding port call efficiency (World Bank, 2024). STSs may fail due to lack of maintenance, poor operational processes, heavy weather, and accidents. STS stoppage should be minimized to avoid negative impact on terminal operation, throughput, and efficiency (Waves Group, 2024).

Accidents involving STSs, especially collisions with ships, pose severe threats, causing structural failures, injuries, fatalities, and multimillion-dollar losses (Transportation Safety Board of Canada [TSB], 2020). Recent incidents, such as the YM Witness colliding with four cranes in Turkey (Schuler, 2024) and a crane collapse in Keelung, Taiwan (Seatrade Maritime, 2024), underscore the urgency of addressing these risks.

Container vessels dock at terminals outfitted with STSs to facilitate the transfer of containers to/from the yard by trucks or automated guided vehicles (AGVs). Literature presents several optimization challenges, such as minimizing STS waiting time by truck scheduling, which indirectly enhances STS efficiency, as derived from graph theory and DDQN (Cheng et al., 2025). Rodrigue's (2025) study noted that longitudinal orientations and site limitations may elevate the probability of collision, including narrow berths. To mitigate uncertainty instances that arise following accidents, Pan et al. (2025) developed hierarchical reinforcement learning for storage allocations. Yang et al. (2025) examined methods for integrating AGV lanes with the scheduling of additional equipment at U-shaped terminals to mitigate emissions, although they did not assess the effects of crane damage.

Historical research, like Li and Vairaktarakis's (2004) examination of container handling techniques and Viss et al.'s (2001) analysis of AGV requirements, underscores the importance of optimizing productivity. Nonetheless, collisions can impede this objective: a vessel colliding with STS can suspend operations, as seen by the Ever Summit incident in Vancouver, when pilot error of distance (2.13 meters) led to the crane's boom collapsing (TSB, 2020). Critically, previous literature lacks empirical data and predominantly depends on simulations, as shown in studies of Hu et al. (2021), X. Li et al. (2021), Hu (2023), Zhao et al. (2024), and Kong and Ji (2024). Moreover, Zhang et al. (2025) from the dataset simulated ripple effects, showing crane failures cause yard congestion and 20% delays. Accordingly, the lack of empirical data is considered a literature gap.

3. Methodology

The study employs quantitative methods to assess the impact of container ship STS gantry crane collisions at a container terminal, utilizing port performance indicators (PPIs) to evaluate the degree of operational disruptions, as these indicators are well-established in maritime literature for measuring terminal efficiency, as noted by Cullinane and Wang (2010) and UNCTAD (2022). Where the hypothesis is: H1: vessel and STS collision affect terminal productivity, efficiency, and cause financial losses; H0: vessel and STS collision do not affect terminal productivity, efficiency, and do not cause financial losses. PPIs, with the support of the trend analysis, provide a comparative assessment of performance pre- and post-incident, underscoring the collision's effect on productivity, resource distribution, and service standards. Moreover, financial metrics are employed to assess the financial losses. The PPIs are shown in Table 1.

The basic data gathered from the port terminal operator and port authority encompasses all raw data necessary for calculating key performance indicators, such as throughput rate, crane utilization, vessel turnaround time, and waiting time. These indicators provide a comparative assessment of performance pre- and post-incident, emphasizing the collision's effect on productivity, resource allocation, and service levels, alongside the financial data required to quantify financial losses. Secondary data was gathered from several sources, including port authority records, terminal operator documentation, shipping lines, gantry manufacturers, and industrial reports and surveys, to document the quantitative and qualitative dimensions of the terminal's activities prior to and after the collision.

Table 1: Assign PPIs

No.	Name	Description / Objective	Formula	Rationale behind choosing PPI
1	Average Anchor Time	Time between the start and end of the stay at anchor	Σ Hours at anchor / No. of vessels	The waiting time of vessels prior to berthing is commonly utilized as an indicator of congestion.
2	Average Time in Port (turnaround time)	The time the vessel spends in port, i.e., from its arrival to its departure from the port.	Σ (Time of Departure – Time of arrival port) / N° of vessels	Ship turnaround time is a key service KPI in UNCTAD's port performance analysis and global port performance reporting.
3	Average Gross Berthing Time	The time the vessel spends at its berth, from throwing first mooring line to removing the last mooring line.	Σ (Time of last line – Time of first line) / N° of vessels	Berth time and occupancy are fundamental to berth-capacity analysis
4	Average Net Working Time	Time from the start of cargo to the end of cargo operations	Σ (Time end cargo – Time start cargo) / N° of vessels	UNCTAD training materials on terminal productivity highlight the significance of including or excluding delays and breakdowns in performance interpretation.
5	Average Berthing Occupancy Rate	The average gross time the vessel stays berthed at the quay over a given period.	Σ (Service Time at berth (in hours) x Meters used) / Σ (Total Available hours x Meters)	Due to decrease operational efficiency or incident-related interruptions, occupancy rises, causing queue and longer anchor time.
6	Working Ship Output (WSO)	Tons (or TEUs) per ship per productive (or working) hours	Σ TEU handled / Σ Productive hours	Output and productivity indicators (throughput per unit time) are extensively utilized in port management measurement frameworks.
7	Berth, Ship, and Operations (BSO)	Tons (or TEUs) per ship per berth hours	Σ TEU handled / Σ Service hours	Research and toolkits often employ berth-hour denominators for performance evaluation.
8	Ship productivity indicator (PSO)	Tons (or TEUs) per ship per port hours	Σ TEU handled / Σ Port hours	End to end time in port measures are extensively utilized for evaluating port performance and the effects of trade facilitation.
9	Crane production rate	measures how much a crane is covering a share of berth productivity for a period	Σ (Crane productivity in TEU per year) / berth through put in TEU per year	fundamental operational drivers of port call performance as indicated by the World Bank

Source: Author

The time frame encompasses a six-month period before the collision and a six-month period after it, regarding the PPIs, while the gantries were installed three years prior to the collision. The financial data encompasses a consistent timeframe to assess overall income before and after, as well as the financial growth of the terminal over the past three years, with the objective of evaluating potential future losses.

This research used a single-case study approach as indicated by Yin (2018), selecting a case purposively due to its rarity and significant operational implications, which will allow for detailed contextual analysis and enhance research robustness. Therefore, the comparative element is incorporated by comparing pre- and post-accident performance within the same terminal, treating the incident as a normal occurrence. This quasi-experimental design isolates the impact of the collision while accounting for external variables, such as market demand fluctuations, through time series analysis.

On the other hand, limitations should be considered where single case limits generalization to other terminals, where factors such as crane design, terminal size, and traffic changes. The focus on PPIs and financial aspects could neglect intangible effects such as safety culture or environmental repercussions, which necessitate future qualitative elaborations.

4. Case study: The accident scenario

The case vessel is a Container Ship, 20 years old. Her length overall (LOA) is 323 meters, and her width is 43 meters, with a total TEU capacity of 8,000+. At the same time, the STS named STS12 and STS13 are 2 Super Boost Panamax Double Handle Frames with safe working loads of 65 and 75 tons, respectively.

According to accident reports from a group of specialists who analyzed the case, and a video recording of the CCTV system, it was found that: During the berthing maneuver at 22:45 local time, the ship's speed reached approximately 2.5 m/s. This high speed generated a high impact energy of approximately 16,750,000 J (16.75 MJ) and a significant impact force of approximately 10,350,000 N (10.35 MN) in the direction of the cranes. The following table illustrates the monitoring of the ship's excessive speed at local time from the bit (0) at the start of the berth to the point of impact between bits 4 and 5, as shown in Table 2.

Table 2: Ship's excessive speed at local time from the bit (0) till collision

The ship is in front of bit no.	Local time	Duration	Speed in m/sec	Speed in knots
0 – 1	22:46:48	00:00:08	3.75	7.29
1 – 2	22:46:59	00:00:11	2.73	5.3
2 – 3	22:47:08	00:00:09	3.33	6.4
4 – start of collision	22:47:17	00:00:09	3.33	6.4
Average speed			**3.28**	**6.38**

Source: Terminal operator & accident reports

The collision may cause damage to the infrastructure of the terminal, such as the quay (Stehmeyer et al., 2016). The impact energy and forces caused the severing and collapse of 7 fenders and deformation of 7 fenders. The following images in Figure 1 show the impact on the starboard side of the ship, causing cuts, deformities, and dents in the bow of the ship; deformities, dents, and cuts in the hull of the ship, as well as other forces in the perpendicular direction that caused the cranes to move and collide with crane number STS11. Taking into consideration weather conditions, wind, and visibility are within normal ranges.

Figure 1: Impact of collision on the ship's side
Source: accident reports

According to the experts report regarding STS12, the right side (Land Side) is severely deformed, buckled, and twisted in the direction of the three axes (X, Y, and Z). The buckling value is approximately 60 mm. The internal support of the Partial Beams is also deformed and buckled, with an internal buckling value of approximately 55 mm. Thirty-two (32) driving and driven wheels of the STS deviated and came out of the track of the berth rail. Undoubtedly, these extreme deviations in different directions (180 degrees) led to maximum stress exceeding the elastic limits, thus causing the wheel motors and gearboxes to reach the yield point. It should be noted that all electric motors were in brake mode during the automatic stop of the STS12. This means that torsional stress occurred in the vertical and horizontal columns, vertical and horizontal supports, and the driving and driven gears. Visual inspection revealed a noticeable oil leak from all gearboxes due to the combined stresses resulting from the enormous impact energy and force, which are directly proportional to the total load and the square of the speed exceeding the limits. In addition to significant deviations in the upper parts, the dimensional differences between the fixed and moving parts are clearly visible as shown in fig 2.

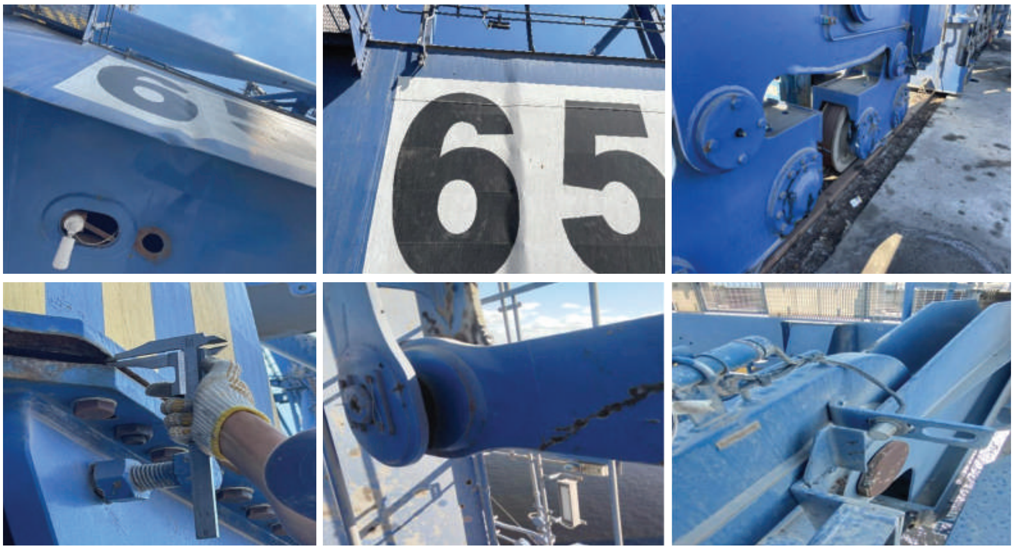

Figure 2: STS12 damage
Source: Accident reports

While STS13 experienced a severe and extensive cut in the seaward side of the port leg (20mm thick) and the internal longitudinal and transverse supports at the Partial Beam level, as well as significant and noticeable deformation, buckling, and twisting, in the direction of the three axes (X, Y, and Z). This demonstrates the stresses and strains resulting from the high energy of the impact and the immense force of the collision on the port leg and the internal longitudinal and transverse supports on the seaward side, deviation and exit of (32) (Driving Wheel & Driven Wheel) from the track of the platform rail. Misalignment and deviation of the out-reach boom arms of the STS, significant deviations in the upper parts, and dimensional differences between the fixed and moving parts, as shown in Figure 3.

Figure 3: Level of damage in STS13
Source: Accident reports

The experts' technical analysis describes the damage and recommends replacing the STS with a new one, as repairs do not ensure proper alignments and stress management. Terminal operations were suspended for 12 hours following the crash. Figure 4 illustrates that about 380 meters of berth length are inoperative owing to required repairs. Furthermore, STS12 and STS13 are temporarily secured in the indicated place pending a final judgment. Where the recommendation complies with the literature, where crane damage leads to high repair or replacement costs (Tran et al., 2018; Bovnegra et al., 2023)

The terminal forfeited one-third of its berth length for an estimated duration of 6 to 12 months until the STS manufacturer's final report is completed, the court renders its decision, the STS rails are repaired to facilitate the movement of STS12 and STS13, and rail extensions are implemented to enable the unobstructed movement of STS11 and STS10.

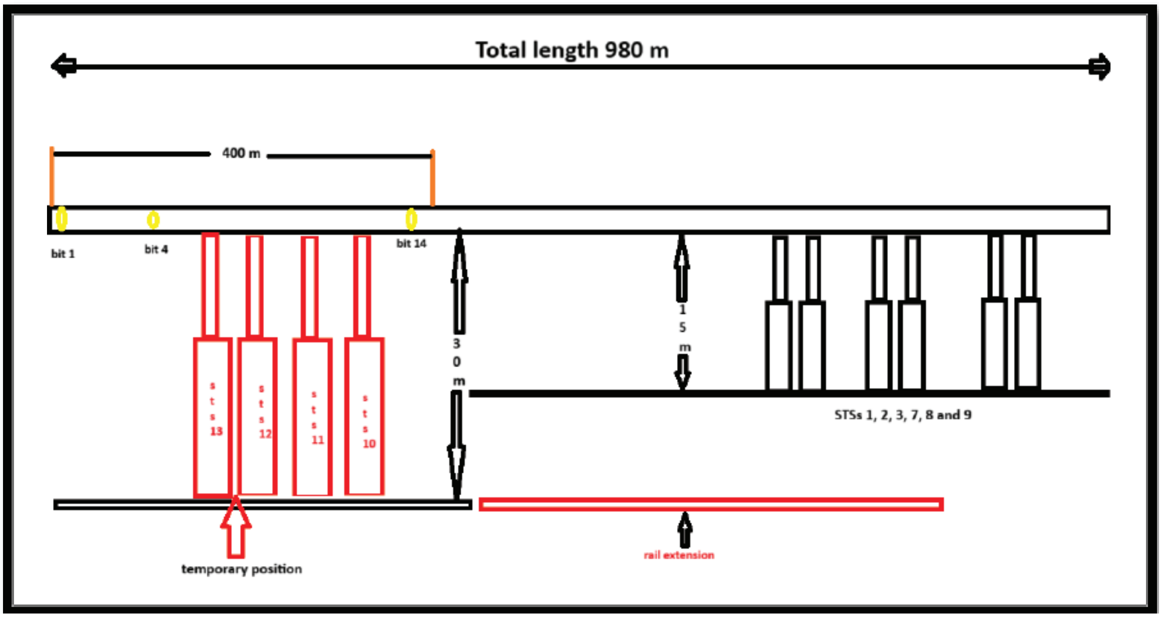

Figure 4: Terminal berth condition after collision
Source: Author, Data source: Terminal operator

5. Results and Discussion

A large amount of work addresses the elements that influence port competitiveness. Recently, researchers have released review articles addressing port selection in container markets (Moya & Valero, 2016). Moya and Valero examine the function of port authorities in the decision-making process of shipping and landside stakeholders regarding port selection. The authors determine that port-selection criteria vary based on whether the influencing elements are within the purview of port authorities or not, and whether the context involves ocean traffic or inland shipping. The principal determinants of port selection for interoceanic traffic are port expenses, geographical positioning, hinterland connectivity, port infrastructure, and port efficiency (Moya & Valero, 2017).

Accordingly, this research utilizes quantitative approaches to examine the impact of accidents between container ships and STS gantry cranes at a container terminal, employing PPIs to measure the extent of operational disruptions and their influence on terminal efficiency, shipping company customers, and financial losses.

5.1. Time indicators

Minimizing waiting times for vessels, so reducing their duration in ports, especially at the quay, is indisputably a priority. The waiting time of a vessel is contingent upon the efficacy of the allocation and scheduling of essential resources, including berthing places, quay and yard cranes, and other cargo handling and transportation apparatus (Siddaramaiah et al., 2021).

Fig 3 presents the terminal time measures before and after the collision, where trend analysis indicated that net-working time and gross berth time are nearly stable trends, while the ship turnround time had an upward trend from an average of 24 hours to an average of 40 hours because of the increase in waiting time, as shown in Fig 3. The upward trend in waiting time reached 20 hours, while the maximum waiting time was 8 hours in seasonality.

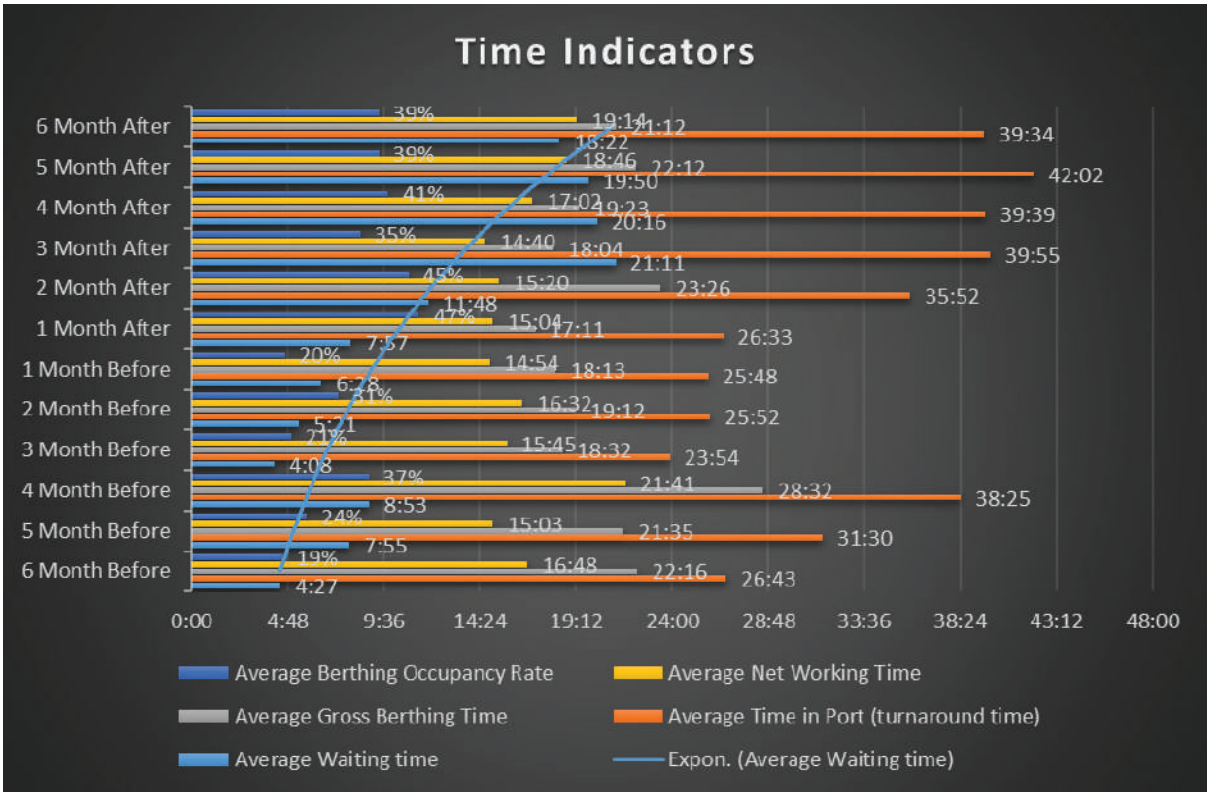

Figure 5: Time indicators
Source: Author

Vessels are designed for navigation; hence, the more they navigate, the greater their earnings. Consequently, ship owners and shipping lines anticipate expedited operations at ports to attain reduced Vessel Turnaround Times (VTTs), thereby augmenting the frequency of loading trips annually. Hence, in our case study, VTT had increased by more than 40% due to the collision.

By analyzing Berth Occupancy Rate (BOR) and waiting time with the number of vessels for a period of 6 months before and after the collision to avoid the effect of seasonality, as shown in table 3 found that there is upward trend in BOR from 24% in the 2nd quarter to 43% in the 3rd quarter, and 39% in the 4th quarter followed by upward trend in average waiting time from average

5.3 hours in the 2nd quarter to average 14 hours in the 3rd quarter and 19 hours in 4th quarter as a complying to queuing theory, in addition to downward trend in number of vessels as indication of start of losing terminal customers.

Table 3: Terminal berth occupancy rate

Date	BOR	NO of Vsl	Average Waiting Time	1/4 BOR	Quarterly Average waiting time
6 Months Before	19%	37	4:27	27%	7:25
5 Months Before	24%	38	7:55		
4 Months Before	37%	47	8:53		
3 Months Before	21%	38	4:08	24%	5:19
2 Months Before	31%	51	5:21		
1 Month Before	20%	36	6:28		
1 Month After	47%	41	7:57	43%	13:39
2 Months After	45%	34	11:48		
3 Months After	35%	26	21:11		
4 Months After	41%	30	20:16	39%	19:29
5 Months After	39%	31	19:50		
6 Months After	39%	33	18:22		

Source: Author

5.2. Ship performance indicators

The operational efficiency of container vessel passages, defined as voyages between two ports, is critical for key container shipping players, including shippers, ship operators, port operators, and port authorities (Cui et al., 2024). The Berth Allocation Problem (BAP) has been the subject of numerous studies due to its intricacy and propensity to have a major impact on VTT. However, it is crucial to note that VTT is not simply reliant on berth allocation; other considerations include the number of moves, the number of STSs, the distance between the yard and the berth, and many others (Hendriks et al., 2012). As a result, it is possible to conclude that the production of a terminal is dependent on the efficient utilization of three essential resources: land, labour, and machinery (Cullinane & Wang, 2010). As a result, the impact of the human factor on container terminal productivity should not be overlooked, even though it is sensitive and difficult to define, gather data, and analyze.

Table 4 provides ship performance indicators where the number of vessels had a downward trend after the collision, SWO, BSO, and average TEU/ship had a normal cyclical trend, which indicates that terminal management is optimizing the utilization of labour and machinery. On the other hand, PSO dropped dramatically after the incident to 21.9 TEU/port-hour after 6 months due to the increase in the waiting time.

Table 4: Ships performance indicators

Month	No. ship/month	Total TEU/month	Average TEU/ship	Average LOA	WSO	BSO	PSO
6 Months Before	37	36116	976.1	186.4	58.4	43.8	36.6
5 Months Before	38	38219	1005.7	188.2	66.8	46.6	31.9
4 Months Before	47	52866	1124.8	190.1	52.1	39.5	29.3
3 Months Before	38	40299	1060.5	180.7	67.3	57.3	44.4
2 Months Before	51	51412	1008.1	187.9	61.0	52.5	38.9
1 Month Before	36	41195	1144.3	193.3	76.8	62.9	44.4
1 Month After	41	42704	1041.6	197.0	69.0	60.6	39.2
2 Months After	34	32769	963.8	199.4	63.0	41.2	26.9
3 Months After	26	27269	1048.8	199.5	71.4	57.9	26.3
4 Months After	30	27612	920.4	195.4	54.0	47.4	23.2
5 Months After	31	27902	900.1	194.1	48.0	40.5	21.4
6 Months After	33	28600	866.7	192.1	45.0	40.9	21.9

Source: Author

Waiting time and PSO are two important indicators for ship operators, where the increase of the former and the decrease of the latter may lead to loss of terminal customers, and from the decreasing number of vessels per month, it can be concluded that the factors have a negative impact on the terminal after the collision.

5.3. STS performance indicators

The STS productivity table 5 delineates the productivity in TEU for each STS in the terminal, together with their respective contributions to terminal berth throughput and the annual net working hours for each STS, thereby highlighting the significance of STS12 and STS13 for the terminal.

Table 5: STSs productivity, share, and net working hours

Year	STS02	STS03	STS07	STS08	STS09	STS10	STS11	STS12	STS13
22/23 STS total production in TEU	586	5504	28911	33899	21365	47170	70795	62086	83791
Crane production rate	0.17%	1.6%	8.2%	9.6%	6.0%	13.3%	20.0%	17.5%	23.7%
Net working Hr/year	34.13	255.78	1833.58	1258.09	772.2	1818.9	2518.43	2142.04	2931.67
23/24 STS total production in TEU	739	4151	57743	50133	23979	47855	50133	57908	84690
Crane production rate	0.18%	1.0%	14.2%	12.4%	5.9%	11.8%	12.4%	14.3%	20.9%
Net working Hr/year	32.55	216.4	2060.26	1681.25	938.0	1996.1	2810.1	2107.12	3015.78
24/25 STS total production in TEU	215	7588	50350	67073	32366	59036	67073	63658	93663
Crane production rate	0.05%	1.6%	10.8%	14.3%	6.9%	12.6%	14.3%	13.6%	20.0%
Net working Hr/year	14.82	326.27	1810.43	2085.75	977.3	2053.9	2877.63	2117.13	2979.85

Source: Author

From table 5, it is noticed that STS12 handles between 13.6% to 17.5% of the quay productivity, while STS13 handles between 20% to 23.7% of the quay productivity, which indicates the importance of both STSs to the terminal because before the collision, both STSs were responsible for an average of 38% of the quay productivity.

By analyzing STS monthly production through the incident year, the output is shown in Table 6, where STS12 &13, starting from the incident, are totally unusable, and STS10 &STS11 have a reduction in their productivity of more than 60% compared to the period before the collision. Moreover, STSs from STS3 to STS09 have increased their use to increase productivity by several thousand TEUs per month, which represents huge stress on the STSs.

Table 6: STSs' monthly productivity for the year 2025

Month	STS02	STS03	STS07	STS08	STS09	STS10	STS11	STS12	STS13
6 Months Before	0	935	3552	4564	4541	5022	7850	3422	6228
5 Months Before	0	854	4183	5374	3951	5169	6513	5540	6635
4 Months Before	0	1894	7395	8843	6893	5773	9483	5427	7158
3 Months Before	0	583	3800	4550	3961	5734	6698	7070	7903
2 Months Before	0	1301	7394	9093	3329	5124	8928	6679	9564
1 Month Before	0	221	3405	5384	1568	6593	7541	6938	9545
1 Month After	0	4695	13048	13054	7311	3023	1573	0	0
2 Months After	0	1987	11208	9882	5307	2043	2342	0	0
3 Months After	0	2828	9565	7382	5298	1294	902	0	0
4 Months After	0	2456	9672	7420	5310	1260	1494	0	0
5 Months After	0	1874	10458	8476	4989	1247	858	0	0
6 Months After	0	2855	6814	6877	5877	3489	2658	0	0

Source: Author

Magala and Sammons (2008) argued that the decision-makers mentioned (shippers, freight forwarders, and shipping lines) approach port selection differently and pursue distinct objectives, contingent upon the role of ports in facilitating their operations. From a marine standpoint, shipping companies structure their service networks to optimize economies of scale (Guy & Urli, 2006) by making decisions that maximize their revenues (Talley & Ng, 2012). Land decision-makers endeavor to reduce expenses (Talley & Ng, 2012): freight forwarders strive to deliver value-added services to their ultimate clients, while shippers face additional decisions within the supply chain (Magala & Sammons, 2008).

Port efficiency is a crucial factor influencing port selection for both inland decision-makers and ocean carriers (Chang et al., 2008; Chou, 2010; Park & Min, 2011; Steven & Corsi, 2012). As shown below in Table 7, a synthesis of the most relevant and commonly cited indicators, as well as their implications for shipping company decision-making, and whether they are affected in the present case or not.

Table 7: The commonly cited indicators affecting shipping company decision-making

No.	Performance Indicator	Description	Source in literature	Impact
1	Port Throughput	This is the volume of cargo handled by a port over a given period and is widely recognized as a crucial measure of port capacity and future development. High throughput indicates a port's ability to handle large volumes efficiently, which is attractive to shipping companies seeking reliable and scalable operations.	(D. Yang et al., 2023; Hwang & Huang, 2025; Kalkschmied & Stricker, 2025)	Negative impact – a slight decrease in port throughput
2	Ship Turnaround Time	The total time a vessel spends in Port, including berthing, loading/unloading, and administrative procedures. Minimizing turnaround time is critical for shipping companies to maintain schedules and reduce costs.	(Johnson & Styhre, 2014; Zhang, Luo, et al., 2025)	Negative impact – increase in turnaround time
3	Waiting Time in Port	Unproductive time is spent by vessels waiting for berths, cargo handling, or administrative processes. Reducing waiting time improves energy efficiency and operational costs for shipping companies.	(Johnson & Styhre, 2014; S. Li et al., 2016)	Negative impact – increase in waiting time
4	Handling Efficiency	Measured as the quantity of cargo handled per hour, this indicator directly affects vessel scheduling and port selection. Higher handling efficiency leads to faster operations and lower costs	(Daryani et al., 2019; Zhong et al., 2020; D. Yang et al., 2023)	Negative impact – decrease rate of TEU/ port time
5	Port Turnover Rate	The number of ship calls or vessel arrivals at a port over a period, reflecting the Port's capacity to process cargo and vessels. While a high turnover rate can indicate efficiency, it may also lead to congestion if not supported by adequate infrastructure	(Yang et al., 2023)	Negative impact – decrease in the number of vessels
6	Berth Utilization and Allocation	The intensity and effectiveness of berth usage, including the matching of ship tonnage to berth capacity. High berth utilization can signal efficient operations, but may also indicate potential congestion and longer waiting times	(S. Li et al., 2016; Zhong et al., 2020)	Negative impact – increase of BOR
7	physical attributes, such as the Number of Cranes	These physical attributes determine a port's ability to accommodate large vessels and handle cargo efficiently. Adequate infrastructure is a key factor in port selection, but studies suggest that focusing solely on physical infrastructure is insufficient without considering operational and technological factors.	((El-Refaei & Idris, 2024; Hwang & Huang, 2025)	Negative impact – 2 STS out of order

Source: Author

Terminal operators have financial difficulties due to escalating operational costs. Shipment delays impede delivery networks. Delays in product deliveries might incur financial losses for companies (N. K. Tran et al., 2024). A decline in client attendance may occur if services are prolonged excessively; shipping companies could easily relocate during periods of inactivity, adversely affecting the terminal's revenue due to the cumulative loss of contracts (Kaizer et al., 2017), as in the case study where the number of vessels using the terminal decreases gradually. Frequent or severe incidents may elevate insurance premiums at the terminal, hence increasing overall costs. Due to claims exerting pressure on coverage, expenses typically escalate in conjunction with the level of risk (Sunaryo & Hamka, 2017). Accordingly, the decline in terminal performance will result in customer attrition, as evidenced by the reduction in the number of vessels frequenting the terminal, as shown in Table 4.

5.4. Financial losses

The terminal is designating the financial year that commences on July 1 and concludes on June 30 of the subsequent year, with the collision occurring at the end of the 2024/2025 fiscal year. As shown in Figure 6, the terminal achieved a throughput of 366,127 TEU in the fiscal year 22/23, generating income from handling fees of $56,929,802.52. In the subsequent year 23/24, throughput increased to 422,268 TEU, resulting in income of $67,399,978.49. For the year 24/25, throughput further escalated to 476,720 TEU, with income amounting to $73,146,135.10, reflecting a 15% yearly income growth. According to the PPIs, the 15% growth won't be reached till the STS is restored to its previous condition, which presents a loss of 6 million USD for the next 2 years, with a total of 12 million USD till the installation of the new STS. In addition to the losses of reputation, where the value of reputational loss = surcharge rate (r) × average value per container (v) × daily throughput (U) × disruption time (T) (Y. Zhang et al., 2020; Y. Zhang & Lam, 2015), with a value of 6,740,000 for the next 2 years.

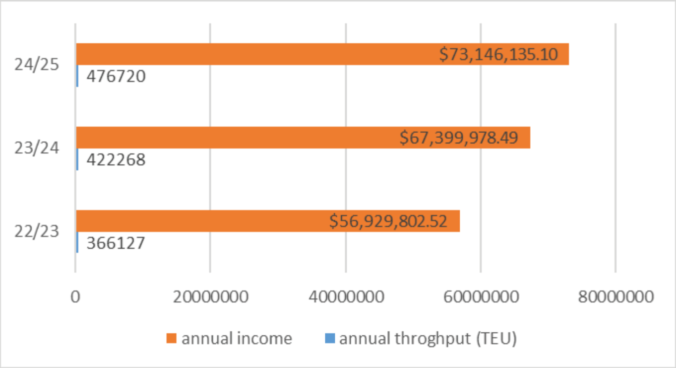

Figure 6: Annual terminal income and throughput
Source: Author

According to bills and official offers, Temporary reinforcement and securing of the crane legs damaged cost 235000 USD, reinstalling the cranes on the rails and re-utilizing the remaining section of the platform cost 764000 USD. The official offer for supplying 2 new STSs is 26000000 USD, and after deducting depreciation, the station will incur an amount of 19200000 USD. The official offer for supplying and installing fenders and STS rail counted for 881500 USD.

Parola et al elucidate the significance of port authorities from a marketing perspective in their work. Utilizing 86 qualitative interviews performed at port authorities, they developed a multidimensional framework for the strategic positioning of these entities. The writers establish five marketing objectives across several levels of contact (Parola et al., 2018). After the incident, the Port needs to focus on marketing to retain and attract customers to create strong bonds through communication and value-added services to ensure customer satisfaction (Caliskan & Esmer, 2019). These incur additional expenses for the planning and execution of the terminal marketing strategy.

6. Conclusion

A collision between a vessel proceeding to berth and terminal STS, resulting from the vessel's excessive speed, inflicted damage on berth finders, damage to two STSs, and the STSs are out of rails, causing damage to the rails, and led to a closure of 35% of the quay length due to STS rail damage. The two STSs malfunctioning, resulting in operational disruptions evidenced by PPIs, including increased BOR from 19% up to 47%, waiting time from 4.5 hours to 21 hours, port time from 24 hours to 41 hours, WSO from 77 to 45, BSO from 63 to 41, and the number of TEUs managed by other STSs as a minimum before and maximum after collision. Additionally, there is a decline in the number of vessels visiting the terminal from 51 to 26, PSO from 44.4 to 21.4, and terminal efficiency, which will ultimately lead to customer attrition and reputational damage, thereby negatively impacting the terminal. The financial losses encompass not only the expenses associated with two STSs but also the costs for berth repairs, STS rail repairs and extensions, a decline in terminal throughput which had been increasing by 15% over the past three years, and the value of reputational damage, totaling almost 90% of the terminal income from the handling operations, in addition to the costs incurred for implementing the marketing plan.

A collision between a vessel and terminal STSs in a medium-sized terminal causes deep operational disturbance, loss of reputation, loss of customers, and financial losses. All these losses need years to recover.

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