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Managing Operational Risk Of Laycan Using Fmea (Failure Mode And Effetct Analysis) – A Case Study Of Tarahan Port

Ahsanul Qoshoshi [1]; Gatot Yudoko [2]
[1,2] School of Business and Management (SBM), Business Administration Study Program
Institut Teknologi Bandung (ITB), Indonesia
Email: [1] ahsanulqoshoshi@gmail.com ,[2] gatot@sbm-itb.ac.id

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ABSTRACT

PT Bukit Asam Tbk (PTBA) is a leading coal mining enterprise with a vital role in supplying energy for both domestic consumption and export markets. One of the company's major challenges lies in managing laycan schedules, which can trigger operational risks, intensify port congestion, and hinder the coal loading process. This study aims to identify operational risks associated with laycan that lead to demurrage and to propose strategies to mitigate these risks at Tarahan Port. The research applies a gap analysis framework supported by Failure Mode and Effect Analysis (FMEA). Data were collected through both primary and secondary sources. Primary data involved focus group discussions designed with FMEA to assess severity, frequency, and detection levels, with insights from thirteen informants: eight from the distribution division, one port supervisor, and four operational support staff. Secondary data were drawn from historical records spanning 2023–2024. The analysis incorporated FMEA and Root Cause Analysis (RCA). Findings revealed 25 root causes using the 5 Why method. The top risks included loading delays at jetty 3, simultaneous vessel arrivals, domestic jetty queues, export documentation delays due to surveyor systems. Recommendations emphasize addressing urgent loading bottlenecks, implementing phased solutions, enhancing cross-team coordination, and ensuring continuous monitoring.

INTRODUCTION

The earth contains abundant natural resources, commonly referred to as natural assets. These are generally categorized into renewable and non-renewable resources, with coal being one of the most significant. Coal remains a primary energy source, particularly for electricity generation. Indonesia ranks among the world's largest producers and exporters of coal, and this fossil fuel has been central to the nation's energy policy since the 1970s. The Ministry of Energy and Mineral Resources (ESDM) set a production target of 900 million tons for 2025, an increase from 775.2 million tons in 2023. Beyond ensuring domestic reserves, Indonesia's strategy emphasizes coal downstreaming, including substituting oil and LPG in transportation with coal-based alternatives. PT Bukit Asam Tbk (PTBA), the sole state-owned coal mining enterprise, plays a strategic role in securing national energy needs while also serving international markets. PTBA has consistently reported rising sales, with a first-quarter net profit of Rp790.9 billion in 2024, supported by 7.3 million tons of coal output a 7% rise from 2023. Sales volume climbed 10% to 9.7 million tons, while exports increased by 4% to 3.8 million tons. These figures highlight both strong market demand and PTBA's ability to expand production capacity to meet customer needs and leverage global opportunities.

Sustaining this growth requires improvements in operational efficiency, particularly in coal distribution. Ship loading activities are critical to ensuring smooth supply chains and meeting delivery targets. A key determinant of efficiency in this process is the effective management of laycan schedules. Xu et al. (2020) emphasize that optimizing laycan scheduling directly enhances coal loading efficiency. By managing laycan accurately, PTBA can guarantee timely delivery, minimize costs, and improve customer satisfaction. Laycan, or "laydays and canceling dates," represents the agreed window between the coal shipper and vessel operator for loading operations. It specifies the earliest and latest permissible loading dates (Bouzekri et al., 2021). Proper scheduling reduces port congestion, shortens vessel queues, and prevents costly demurrage. However, PTBA currently faces challenges such as mismatches between scheduled and actual vessel arrivals and overlapping laycan periods. These issues elevate operational risks, disrupt coal loading activities, and hinder port productivity.

LITERATURE REVIEW

Laycan and Laytime

Laycan is an abbreviation of "Laydays and Cancelling Date" in charter-party contracts in the shipping industry, especially used in voyage charters. Laycan is used in the shipping industry to describe the agreed time span between the owner and the charterer. This time span includes the start and end dates when the ship must be ready to load. If the ship arrives outside the laycan period either earlier or later, the charterer can cancel the contract or apply certain penalties. Laycan is an important element because it determines the efficiency and timeliness of port operations. This time span is expressed in two dates, namely the start date as the earliest time the ship must be available, and the end date as the latest deadline for the ship to start loading (Bouzekri et al, 2021). Laycan can be interpreted as a period or time span of the start and end dates used to carry out loading. Operational factors that can affect laycan are port congestion, unfinished paperwork, cargo not ready, poor communication between stakeholders.

After the ship arrives at the loading port, the charterer must be ready to start loading its cargo so as not to exceed its laytime. Laytime is the time limit given to the charterer to carry out loading or unloading activities without being charged additional fees (Sun et al, 2020). According Singh (2011) laytime is the period of time during which the vessel will be at the charterers disposal for the loading and unloading of the cargo. This time is usually agreed upon in the ship charter agreement and is calculated based on a specific time unit such as days or hours. According to Song and Panayides, 2015 if the renter exceeds the laytime, they will be charged a fine called demurrage.

Laycan and laytime are two main clauses in a Voyage Charter Party. This clause specifies the period within which the shipowner must issue a Notice of Readiness (NOR) to the charterer that the vessel has arrived at the port of loading and is ready in all respects to load. If the NOR is not issued during the laycan, the charterer has the option to cancel the charter. Once the vessel arrives at the port of loading, the charterer must be ready to start loading her cargo in order not to exceed her laytime. Laytime begins when the NOR is received. If the charterer exceeds the laytime, a predetermined penalty called demurrage will be imposed (Bouzekri et al, 2021).

The timely arrival of the vessel is important to the charterer for several reasons above. If the vessel is late, the charterer has the right to cancel the charter. If the vessel is unlikely to arrive at the loading port on time and the delay is not caused by events beyond the owner's control, this will automatically terminate the shipowner's agreement to send their vessel to the loading port regardless of the delay in arrival beyond the original cancellation date (Melani, 2022). The charterer can cancel even though there is no fault of the shipowner for example if the vessel is delayed due to bad weather en route.

Operational Efficiency

Operational efficiency can be defined as the ability of a company to produce maximum output by utilizing minimal resources without sacrificing product or service quality (Ariyandi and Purwanti, 2025). Operational efficiency is also an important factor in a company's financial performance, especially in emerging markets such as Indonesia (Judijanto, 2024). Efficient operations can improve environmental performance with companies with high productivity and low emissions tending to be more profitable (Amarasuriya et al., 2024). Meanwhile, in developing countries, operational efficiency is key to overcoming infrastructure and resource allocation challenges (Henríquez-Machado, 2024). So operational efficiency in this case reflects the port's ability to utilize resources to maximize throughput and reduce ship waiting times.

Loading rate

Loading is an activity carried out to insert material or sediment from excavation results into a means of transport carried out after eviction activities using loading equipment and filled into the means of transport (Lestari, 2022). This loading activity aims to move the material from the demolition into the means of transport. In the context of ports, loading specifically refers to the process of moving coal or other goods from the dock to the ship that will carry the goods to export or domestic distribution destinations. Efficiency in the loading process is essential to increase port productivity, reduce operational costs, and speed up delivery times.

Loading rate is a loading speed that has been determined by the owner of the goods (shipper) which must be achieved within 24 hours (Lestari, 2022). Loading rate can also be interpreted as a matter of time being important where several things that support smooth loading include schedules (Atha, 2023).

Demurrage

Demurrage is an agreed payment due to a breach of contract that causes the ship to be late either during loading or unloading or during loading (John Schofield in the book Laytime and Demurrage Fourth Edition, 2000). Demurrage is also defined as an amount of money agreed upon by the charterer and must be paid to the shipowner in connection with the delay of the ship outside of the rest period which is not the responsibility of the shipowner. Demurrage will not be subject to laytime exceptions unless specifically stated in the Charter Party. The Commercial Shipping Handbook (Peter Brodie, 2006) explains that demurrage is a provision between the charterer and the shipowner relating to fines due to the ship being late when loading or unloading at the port.

Root Cause Analysis

Root Cause Analysis (RCA) is defined as a systematic process used to identify and address the root causes of a problem, incident, or issue, rather than simply treating the symptoms. The purpose of RCA is to determine why a problem occurred in the first place and to implement corrective actions that prevent the problem from recurring. The 5 Whys method is used for structured RCA analysis (British Retail Consortium, 2012). Researchers continually ask "Why?" questions until they reach a conclusion. The recommended minimum number of questions is generally five times the number of questions that need to be asked. While additional questions are sometimes necessary or helpful, it's important to ensure that questions continue until the root cause is identified.

Failure Mode and Effect Analysis (FMEA)

FMEA is a structured procedure to identify and prevent as many failure modes as possible (Casadei et al., 2007). According to Omdahl (1998), FMEA is a technique used to define, identify and eliminate known and potential failures, problems and errors in a system, design, process and/or service before it reaches the customer. Sihombing and Pujotomo (2018) stated that this technique is commonly used to measure the level of reliability of a system in determining the effects of a system failure. So, FMEA analysis focuses on the causes of failure and the mechanisms by which failure occurs. According Kurniawan et al. (2021) Failure Mode and Effect Analysis (FMEA) is a technique used to determine, identify, and reduce known or potential failures, problems, errors, and so on of a system, design, process, and service before it reaches the consumer.

The application of FMEA first identifies possible failures. The measurements include the probability of failure occurring (Occurrence O), the impact caused by failure (Severity (S), and the capacity to prevent and reduce failure (Detection/D) then the three measurement indicators are used to calculate the Risk Priority Number (RPN) value. mawhich is used as a basis for prioritizing corrective actions against the most significant risks (Rakesh et al., 2013).

METHODS

This study employed a descriptive quantitative research approach. Data were obtained from both primary and secondary sources. The primary data were collected through a focus group discussion (FGD) designed using the Failure Mode and Effect Analysis (FMEA) framework to assess severity, occurrence, and detection levels (Rakesh et al., 2013). A total of 13 respondents participated, including eight members of the distribution team, one port supervisor, and four from the operational support division. Secondary data consisted of historical operational records from 2023 and 2024, covering variables such as demurrage, laycan scheduling, waiting times, and loading volumes. For data analysis, the study applied FMEA alongside the “5 Whys” Root Cause Analysis (RCA) method (British Retail Consortium, 2012). The qualifications of the respondents are outlined as follows:

Table 1 Respondent Qualifications

No.	Position	Work Experience (Years)
1	Distribution	9
2	Distribution	13
3	Distribution	10
4	Distribution	5
5	Distribution	7
6	Distribution	9
7	Distribution	4
8	Distribution	8
9	Port Supervisor	17

No.	Position	Work Experience (Years)
10	Operational Support	10
11	Operational Support	8
12	Operational Support	9
13	Operational Support	7

RESULTS

Risk Identification

The identification of risks was carried out to gain a thorough understanding of operational risk factors contributing to demurrage costs in coal export operations at Tarahan Port. An analysis of historical export data for the 2023–2024 period revealed that demurrage issues did not stem from a single cause, but rather from a combination of multiple interconnected operational risks. The following section outlines the sources of these operational risks along with the frequency of incidents recorded in the 2023–2024 operational data at Tarahan Port.

Table 2 Causes of Operational Risk Based on Historical Data for 2023 and 2024

Description	2023	2024	Total
Loading queue because the jetty is still occupied by the previous vessel (Jetty 3)	0	4	4
Vessels arriving simultaneously	8	4	2
Queue at domestic Jetty 1			
Queue at domestic Jetty 3			
MPV (Multi Purpose Vessel) surveyor block system, causing PEB/export notification delays (2 days)			
Overload			
Conveyor shipping line malfunction			

Table II presents the various causes of operational risk. The most frequent issue was loading and unloading queues caused by the jetty still being occupied by the previous vessel (Jetty 3), which occurred 74 times in total 30 incidents in 2023 and rising to 44 incidents in 2024. The second most frequent risk was vessels arriving simultaneously, recorded 72 times overall 28 incidents in 2023 and 44 incidents in 2024. The risk of queuing at the domestic Jetty 1 occurred 9 times, all in 2024, while queuing at the domestic Jetty 3 occurred 4 times, also in 2024. The risk associated with the MPV (Multi-Purpose Vessel) surveyor block system, which caused a two-day delay in the Export Goods Declaration, was recorded 2 times in 2024. Meanwhile, the risks of overloading and conveyor shipping line malfunctions each occurred once in 2024.

Failure Mode and Effect Analysis (FMEA)

The Failure Mode and Effect Analysis (FMEA) in this study was carried out to identify and assess potential failures in the coal export process at Tarahan Port that contribute to vessel demurrage. This approach prioritizes issues based on their severity, likelihood of occurrence, and level of detectability for each failure mode identified in Table 2 The following table presents the calculation of the Risk Priority Number (RPN):

Table 3 FMEA Analysis Based on Historical Data 2023–2024

Code	Risk	S	O	D	RPN	Priority
1	Loading queue because the jetty is still being used by the previous vessel (Jetty 3)	7	8	3	168	1
2	Waiting queue at domestic Jetty 1	4	2	6	48	3
3	Waiting queue at domestic Jetty 3	4	1	6	24	4
4	Simultaneous vessel arrivals	7	8	3	168	2
5	MPV (Multi-Purpose Vessel) surveyor block system causing 2-day delay in export notice	2	1	10	20	5
6	Overloading	2	1	8	16	7
7	Conveyor shipping line malfunction	2	1	9	18	6

Risk Matrix Mapping

The results of the FMEA analysis were further developed into a risk matrix to provide a clearer picture of the distribution and intensity of risks. Each risk sub-criterion was mapped by considering the values of Severity, Occurrence, and Detection, which were then categorized using a color-coded system to simplify interpretation for stakeholders. The color scheme was validated through Focus Group Discussions (FGDs) with relevant stakeholders to ensure its applicability in practice. The Risk categories are divided into three levels: green for low risk with an RPN value below 20, yellow for medium risk with an RPN value ranging from 20 to 69, and red for high risk with an RPN value above 70. Furthermore, the ranking system is integrated with this color coding, with ratings 1-4 highlighted in green, ratings 5-7 in yellow, and ratings 8-10 in red. Risks marked in red indicate critical issues requiring immediate mitigation efforts. Each risk sub-criterion is labeled using a specific code that combines the risk criterion code with the sub-criterion code. This coding system not only ensures systematic mapping but also facilitates cross-referencing in subsequent analysis. The complete risk mapping is presented in the following section.

Table 4 Risk Mapping of Operational Risks Based on Historical Data (2023–2024)

Code	Risk Description	S	O	D	RPN
R1	Loading queue because the jetty is still being used by the previous vessel (Jetty 3)				68
R4	Ships arrive simultaneously				68
R2	Waiting in queue at domestic Jetty 1				48
R3	Waiting queue at domestic Jetty 3				24

Code	Risk Description	S	O	D	RPN
R5	MPV (Multi-Purpose Vessel) surveyor block system causing 2-day delay in export notice			0	0
R7	Conveyor shipping line malfunction				8
R6	Overloading				6

Risk Mapping and Priority Determination

The risk mapping process enables the identification of priority risks that form the focus of proposed business solutions. Attention is directed toward medium and high-level risks (highlighted in yellow and red), given their substantial impact on operational performance. These include loading and unloading queues caused by jetty usage overlap (Jetty 3), simultaneous vessel arrivals, waiting queues at domestic Jetty 1, waiting queues at domestic Jetty 3, the MPV (Multi Purpose Vessel) surveyor block system that delays the Export Goods Declaration (PEB) by two days.

Root Cause Analysis (RCA)

Root Cause Analysis (RCA) was applied to uncover the underlying causes of operational disruptions in coal loading activities at Tarahan Port. This method identifies the fundamental triggers of inefficiencies and risks, forming a basis for targeted improvement strategies. Building on the risk identification in the FMEA analysis, RCA was conducted for each priority risk that significantly contributed to laycan issues, high demurrage costs, vessel waiting times, and logistical delays. The 5 Whys method was employed to trace each problem back to its root cause.

1. Loading queue at Jetty 3
   Causes include overlapping jetty usage, lack of synchronization between vessel arrivals and loading times, prioritization of domestic vessels, ineffective manual coordination across operational units, and the absence of an integrated, real-time scheduling system (reliance only on unit-level CCTV tracking).
2. Simultaneous vessel arrivals
   Issues arise because arrival schedules are aligned with laycan provisions in contracts rather than real operational conditions, absence of integrated ETA monitoring and predictive systems, high data dynamics, bureaucratic manual coordination, lack of data transparency, and limited budget/digitalization priorities.
3. Waiting queue at domestic Jetty 1
   Root causes include policy prioritizing domestic vessels, shared use of limited jetty facilities, absence of infrastructure expansion to separate domestic and export flows, and management's emphasis on efficiency and target achievement over operational realities.
4. Waiting queue at domestic Jetty 3
   Root causes include policy prioritizing domestic vessels, shared use of limited jetty facilities, absence of infrastructure expansion to separate domestic and export flows, and management's emphasis on efficiency and target achievement over operational realities
5. MPV surveyor block system
   Problems stem from government vendor systems blocking verification due to errors or non-conformities in submitted export data, lack of pre-validation processes, absence of SOPs, and no system integration between PTBA and the government vendor.

Business Solution

Drawing from the comprehensive Failure Mode and Effects Analysis (FMEA) and overall risk ranking, the proposed business solution is designed to strategically address the most critical issues in order to mitigate operational risks and close the business value gap. The solutions outlined below are tailored to the root causes of each identified risk at Tarahan Port.

1. Loading queue due to jetty still being used by the previous vessel (Jetty 3)

- Cause: Jetty occupied by previous vessel, preventing immediate loading → Solution: Slot Time Management using Google Sheets.
- Cause: Lack of synchronization between arrival and loading times, with domestic ships prioritized → Solution: Centralized Vessel Scheduling via Google Sheets (showing ETA, readiness status, and priority).
- Cause: Ineffective, manual coordination among operational units → Solution: Google Workspace-based Digital Collaboration Platform (integrating chat, file sharing, and loading dashboards).
- Cause: Absence of a real-time integrated corporate system → Solution: Integrated Operations Dashboard (Google Sheets + Google Data Studio/Looker Studio).
- Cause: Existing system limited to CCTV tracking at unit level, with tiered decision-making and data non-transparency → Solution: IoT integration of CCTV feeds with spreadsheets for centralized monitoring.

2. Simultaneous vessel arrivals

- Cause: Arrival schedules not aligned with field conditions or delivery plans → Solution: ETA adjustment via Google Sheets.
- Cause: TA (Time of Arrival) planning still based on contract laycan, ignoring field realities like jetty queues → Solution: Digitalized Online Forms for ETA confirmation by agents, updated daily in spreadsheets.
- Cause: No integrated real-time ETA monitoring/prediction system → Solution: Simplified Integrated Dashboard via Google Data Studio (showing ETA, vessel status, jetty capacity).
- Cause: Past integration efforts failed due to data complexity and coordination gaps → Solution: Gradual data integration using shared Google Sheets + Google Data Studio dashboards.
- Cause: Manual and bureaucratic coordination, lack of transparency, no digital collaborative platform, low priority on digitalization → Solution: Shared cross-unit dashboard (Google Workspace) with real-time vessel, stock, and weather updates.

3. Queue at Domestic Jetty 1

- Cause: Policy prioritizing domestic vessels → Solution: Dynamic jetty slot allocation with Google Sheets.
- Cause: Urgency of domestic coal supply for energy needs and contractual obligations → Solution: Priority Matrix & Scheduling Guidelines with Google Sheets.
- Cause: Shared use of Jetty 1 due to limited facilities → Solution: Shared Scheduling Dashboard with Google Data Studio.
- Cause: No infrastructure expansion to separate domestic and export flows → Solution: Google Sheets-based Shared Scheduling System.
- Cause: Focus on cost efficiency and targets without considering field constraints → Solution: Google Workspace Digital Collaboration Platform with shared dashboards for status, schedules, and readiness.

4. Queue at Domestic Jetty 3

- Cause: Policy prioritizing domestic vessels → Solution: Dynamic jetty slot allocation with Google Sheets.
- Cause: Urgency of domestic coal supply for energy needs and contractual obligations → Solution: Priority Matrix & Scheduling Guidelines with Google Sheets.
- Cause: Shared use of Jetty 1 due to limited facilities → Solution: Shared Scheduling Dashboard with Google Data Studio.
- Cause: No infrastructure expansion to separate domestic and export flows → Solution: Google Sheets-based Shared Scheduling System.

- Cause: Focus on cost efficiency and targets without considering field constraints → Solution: Google Workspace Digital Collaboration Platform with shared dashboards for status, schedules, and readiness

5. MPV (Multi Purpose Vessel) surveyor block system delaying PEB/export notifications by 2 days

- Cause: Government vendor surveyor system blocks verification, no pre-validation process → Solution: Digital Pre-Validation using Google Sheets or Excel Online with scripts.
- Cause: Errors in data entry, lack of pre-validation → Solution: Automated data validation via spreadsheets or simple web tools.
- Cause: Export documents not meeting required format/standards → Solution: Template-based digital documentation (spreadsheet or online forms with validation rules).
- Cause: No system integration between PTBA and government vendors → Solution: Google Workspace-based shared dashboards for joint data verification.

Implementation Plan

Following the proposed solutions, an implementation plan is required to ensure structured execution. The plan should be carried out in a phased, systematic, and prioritized manner—taking into account readiness levels, activity complexity, and urgency. The objective is to guarantee effective and efficient implementation while maximizing the impact on operational improvements. The detailed implementation plan is presented in the following table.

Table 5 Phase I Implementation

No.	Activity	PIC	Schedule
1	Create a Google Sheets template for time slots	Operational Support Teams, Distribution Teams, Port Supervisor	Q1 (M1)
2	Create a special Google Form for filling in ETA, laycan, and ship position (to be completed by the agent 1 day before arrival)	Operational Support Teams, Port Supervisor, Distribution Teams	Q1 (M1)
3	Create a Google Sheets template for ship ETA input (ETA + field condition data: queue, loading progress, jetty availability, ship status, stock, weather)	Operational Support Teams, Port Supervisor	Q1 (M2–M3)
4	Create a Google Sheet containing ETA, readiness status, and priority column (export/domestic)	Operational Support Teams, Distribution Teams, Port Supervisor	Q1 (M2–M3)
5	Develop a priority matrix (domestic vs. export) based on urgency with Google Sheets	Distribution Teams	Q1 (M1–M3)
6	Create Google Sheets/Excel Online with script/validator template for MPV export data pre-validation (ship, quantity, HS code, buyer)	IT, Distribution Teams	Q1 (M2–M3)
7	Create digital input forms with automatic validation (dropdown, range check, mandatory fields) using spreadsheets + automated scripts or a simple web app	IT, Distribution Teams	Q1 (M2–M3)
8	Conduct routine weekly inspections of bearings, idlers, belts, and conveyor motors, then input results into a digital form (Google Form or Google AppSheet)	Operational Support Teams, Port Supervisor	Q1 (M1–M2)
9	Perform periodic condition monitoring with portable sensors & manual data input to a shared Google Sheet	Operational Support Teams, Port Supervisor	Q1 (M2–M3)

No.	Activity	PIC	Schedule
10	Create a dedicated collaboration space in Google Chat/Spaces for vessel scheduling	Distribution Teams	Q1 (M1)
11	Create shared folders & dashboards in Google Drive for export documents	Distribution Teams	Q1 (M2–M3)

Table 6 Phase II Implementation

No.	Activity	PIC	Schedule
1	Set up Google Workspace and unify chat, files, and loading status dashboard	Port Supervisor, Operational Support Teams	Q2 (M4–M6)
2	Develop an integrated operations dashboard (Google Sheets + Google Data Studio: ETA, loading rate, stock, weather)	Operational Support Teams, Port Supervisor	Q3 (M7–M9)
3	Create a Google Sheet to collect ETA, vessel status, and jetty capacity data	Operational Support Teams, Port Supervisor	Q2 (M4–M5)
4	Create Google Sheets + Google Data Studio data per unit in stages (Ship movement & ETA, Field conditions & facility availability, Stock availability & supply readiness)	Operational Support Teams, Port Supervisor, Distribution Teams	Q2–Q3 (M5–M8)
5	Create a Google Sheets visual dashboard of jetty capacity (real-time)	Operational Support Teams, Port Supervisor	Q2 (M4–M5)
6	Create a Google Sheets of ship schedules from related units by synchronizing ETA data with field conditions	Operational Support Teams, Distribution Teams, Port Supervisor	Q2–Q3 (M5–M7)
7	Create export document templates that conform to government vendor formats with spreadsheets	IT, Distribution Teams	Q2 (M4–M5)

Table 7 Phase III Implementation

No.	Activity	PIC	Schedule
1	Install sensors/IoT or update digital manual logs on loading tools	IT, Operational Support Teams, Port Supervisor	Q4 (M10–M12)

DISCUSSION

This study revealed that the risk of laycan at Tarahan Port is due to loading and unloading queues caused by overlapping berths (Pier 3) and simultaneous vessel arrivals. These findings confirm a previous study by Bouzekri et al. (2021), which highlighted the importance of accurate laycan scheduling in improving port efficiency. Misalignment between contractual laycan arrangements and actual operational conditions, such as port congestion, domestic vessel prioritization, and limited digital monitoring, creates systemic delays that directly impact coal distribution performance.

This analysis also shows that the current coordination system, which still relies on manual processes and unit-level tools, is inadequate for managing complex coal logistics. To address this, a practical digital solution using an integrated dashboard and collaborative platform can increase transparency, synchronize vessel arrivals, and reduce administrative delays. This solution provides a cost-effective way to mitigate operational risks without requiring large-scale infrastructure investments.

From a business perspective, improved scheduling efficiency and reduced demurrage costs will not only improve PTBA's operational performance but also strengthen its competitiveness in the international coal market. However, long-term resilience will require structural improvements, to balance domestic supply obligations with export commitments.

CONCLUSION

Based on the research questions and analytical findings, this study concludes that seven operational laycan risks contributed to high demurrage costs at Tarahan Port during 2023–2024. These risks include: loading and unloading queues due to the jetty still being occupied by the previous vessel (jetty 3), domestic vessel queues at jetty 1, domestic vessel queues at jetty 3, simultaneous ship arrivals, the MPV surveyor block system causing a two-day delay in PEB issuance, overloading, and conveyor line disruptions. The improvement strategies proposed to minimize demurrage in coal export operations are aligned with tailored business solutions for each root cause at Tarahan Port. The recommendations emphasize prioritizing high-impact areas, with an immediate focus on resolving the top-ranked issue loading delays at jetty 3 alongside optimizing vessel scheduling to prevent overlapping arrivals. Strong collaboration between port, distribution, and operational support units is also essential to ensure an integrated and effective execution. Finally, the phased implementation strategy consists of three stages: Phase 1 (Immediate & High Impact), Phase 2 (Medium-Term & Sustainable Improvement), and Phase 3 (Long-Term & Cultural Transformation).

LIMITATION

This study is limited by its focus on a single case study at Tarahan Port, which may restrict the generalizability of the findings to other ports or industries with different operational contexts. The risk assessment relies primarily on the FMEA method, which, while systematic, is based on subjective scoring and expert judgment that may introduce bias or variability in prioritizing risks. Data availability and accuracy also posed constraints, as the study depended on historical records, operational reports, and interviews that may not fully capture real-time conditions or all underlying risk factors. Furthermore, the analysis emphasizes operational risks of laycan within the period of 2023–2024, thereby not considering potential external influences such as regulatory changes, global market dynamics, or technological advancements that could affect long-term risk management strategies.

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