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Managing Demurrrage Using Fmea (Failure Mode And Effect Analysis) – A Case Study Of Coal Mining Corporation In Indonesia

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ABSTRACT
PT CMC (Coal Mining Corporation) is an Indonesian coal mining company that plays a role in meeting both domestic and export energy demands. At present, loading and unloading schedules for ships frequently overlap due to prolonged vessel scheduling, leading to increased demurrage costs. The arrival of multiple vessels at the same time often results in congestion, queues, and delays in loading and unloading operations. This situation not only escalates demurrage expenses but also undermines port operational efficiency and raises operational risks. To address these business challenges, this study aims to identify operational risks and propose effective improvement strategies to minimize demurrage. The research adopts a gap analysis approach integrated with Failure Mode and Effect Analysis (FMEA). A questionnaire was designed based on FMEA principles to assess severity, occurrence, and detection levels. Data were collected from 15 respondents, consisting of three distribution team members, seven from the Palembang dock team, and five from the transportation handling team. The findings, derived from a root cause investigation using the 5 Whys method, reveal 25 underlying causes of the problem. Based on the Risk Priority Number (RPN), the controllable risks in order of priority are: (1) waiting for cargo barges due to their unavailability, (2) simultaneous ship arrivals (overlapping schedules), (3) floating crane unavailability as it is still servicing another vessel, (4) queuing caused by prioritizing domestic vessels for loading, and (5) failure to meet the target loading rate. Recommended actions include: prioritizing high-impact issues by focusing first on the most critical problems, particularly barge resource allocation; implementing solutions systematically across all relevant operational areas; fostering cross-functional collaboration between the distribution,

Palembang pier, and transportation handling teams to ensure integrated execution; adopting a phased strategy for short-, medium-, and long-term implementation; and establishing continuous performance monitoring.

INTRODUCTION

Mining activities in Indonesia trace their origins to coal mining in Ombilin, West Sumatra, where the Netherlands extracted 500,000 tons to meet its own needs. The coal industry in Indonesia has distinct characteristics shaped by its archipelagic geography and government regulations, particularly the Domestic Market Obligation (DMO), which requires coal producers to prioritize domestic supply before exporting. Additionally, global market factors such as coal price volatility, shifts in energy policies among major importing countries, and the global transition toward cleaner energy sources significantly affect coal distribution patterns both nationally and internationally. Modern mining in Indonesia began in 1967 with the enactment of Law No. 1/1967 on Foreign Investment, followed by Law No. 11/1967 on Basic Mining Provisions. Both laws are derived from Article 33 of the 1945 Constitution, which governs the management of Indonesia's natural resources. These regulations opened the mining sector to investment from both domestic (PMDN) and foreign (PMA) private companies. Coal sales to the international market are conducted through direct contracts with buyers, auctions, or via trading intermediaries. Indonesia's primary coal export destinations include China, India, Japan, and South Korea.

PT CMC (Coal Mining Corporation) is one of Indonesia's coal mining companies, contributing to both domestic and international energy supply. The company has experienced significant sales growth, with first-quarter 2024 net income reaching IDR 790.9 billion and coal production hitting 7.3 million tons a 7% increase from the 6.8 million tons recorded in 2023 (Internal Company Source, 11/02/2025). The growth in PT CMC's sales is closely tied to its strategic approach, particularly the comprehensive implementation of operational optimization. The company consistently pursues efficiency across all stages from mining operations and transportation to distribution to ensure smooth coal production and delivery to both domestic and international customers. A critical factor in achieving distribution efficiency is the optimization of vessel loading operations at the port. This process is vital to adhering to agreed shipping schedules, thereby preventing costly delays. Loading delays can result in demurrage fees, which place a significant financial burden on PT CMC. Consequently, an integrated and efficient supply chain management strategy is essential to enhancing the company's competitiveness and profitability.

The loading schedule refers to the timeframe agreed upon between the buyer (such as a power plant, factory, or trading company) and the seller (PT CMC) to ensure that a vessel arrives and is ready to begin loading within the designated period. Any inaccuracy or delay in the loading process can lead to serious consequences, including order cancellations and demurrage charges. Demurrage is a penalty imposed when a vessel remains in port beyond the allotted time, and such delays can stem from factors like port congestion, administrative bottlenecks, or adverse weather conditions. Effective management of vessel scheduling and loading windows is therefore crucial to avoiding demurrage fees, which can substantially increase shipping operational costs. Moreover, reducing these delay-related costs can positively impact overall company performance (Kim & Chou, 2024). Currently, overlapping loading and unloading schedules have driven up operational expenses and demurrage costs. Ships arriving earlier or later than scheduled often face queues or loading/unloading delays, resulting in extended berthing times. This situation not only heightens demurrage expenses but also undermines port efficiency and elevates operational risks. Such risks can be systematically identified through the Failure Mode and Effect Analysis (FMEA) method a structured risk assessment tool that evaluates potential failures in port operations by measuring their severity, frequency of occurrence, and detectability, then prioritizing them based on their Risk Priority Number (RPN). In coal export operations, it is important to recognize that not all aspects of port activity can be fully controlled due to inherent variability and operational uncertainties. Anticipating these risks is therefore a strategic necessity for improving export performance and minimizing demurrage costs.

This study is designed to critically assess existing operational risks, identify factors contributing to demurrage costs, and recommend actionable measures for their reduction. It seeks to gather and analyze data, extract insights, and translate these findings into strategies and interventions that enhance operational efficiency. Accordingly, the main objectives of this research are: (1) to identify operational risks that lead to demurrage in coal export activities at the Palembang docks, and (2) to propose targeted improvement strategies that can reduce demurrage and improve the efficiency of coal export operations at the Palembang docks.

LITERATURE REVIEW

Despatch

Despatch can be interpreted as incentive money given by the ship owner to the ship charterer for loading and unloading less than the time specified in the contract (Cahyanti, 2021). Meanwhile, according to John Schocield in the book Laytime and Demurrage (2000), despatch is a fee requested from the ship owner based on an agreement to be paid to the ship charterer when the loading and unloading process is completed faster than the laytime.

Demurrage

According to John Schofield in his Laytime and Demurrage (2000), demurrage is defined as an agreed payment due to a breach of agreement that causes the ship to be late either during unloading or loading. While demurrage is also defined as the amount agreed by the charterer and must be paid to the ship owner in connection with the delay of the ship outside the rest time which is not the responsibility of the owner. 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 ship owner relating to fines because the ship is delayed when loading cargo or unloading cargo at the dock.

Laytime

Adascalitei Oana in the book Legal Provisions On Laytime and Demurrage In Charterparties (2013) defined laytime as the determinant of time and number of days directly with an agreement at a certain time period, but bad weather is not included in the calculation of laytime because it can affect the loading or unloading process. Laytime is the calculation of time calculated from the process of docking at the dock and loading and unloading the ship until the end of the loading and unloading process.

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). 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.

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).

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. The initial stage in conducting an analysis using FMEA to identify problems during the production process is to find the highest RPN (Risk Priority Number) value which is used as a basis for prioritizing corrective actions against the most significant risks (Rakesh et al., 2013).

METHODS

Research design is a framework of research methods and techniques chosen by a researcher to conduct a study. A common type of research design is descriptive. FMEA was chosen to identify risks based on PT CMC's historical data from 2022 to 2023 to mitigate operational risks and thereby reduce demurrage. Afterward, the root cause of each risk will be identified using the RCA 5 Whys method. Interviews will be used as the data collection method.

RESULTS

Risk Identification

The following are the reasons for demurrage on vessel along with the number of incidents recorded based on historical operational data at Palembang pier transshipment Estuary Banyuasin during the period 2022 to 2024.

Table I Causes of Demurrage Based On Historical Data 2022-2024

Description	2022	2023	2024	Total
Waiting for cargo barge (cargo barge was not yet available)	3	2	21	26
Ships arriving simultaneously (overlapping time arrival)	1	3	18	22
Floating crane is not available because of not having completed servicing the previous vessel	1	5	13	19
Queues due to loading priority for domestic ships	3	2	7	12
Disruption of licensing procedures and administrative systems (Mining Operation Monitoring System/MOMS, verification results report/LHV, export notification of goods/PEB, Ship To Ship/STS)	0	3	5	8
Reduced coal supply	4	4	0	8
Bad weather and high tides	0	1	5	6
Floating crane is damaged or under maintenance	2	3	0	5
Coal quality decreases due to weather	0	0	5	5
Sticky material due to rain and high humidity	0	0	5	5
Target loading rate not achieved	2	1	0	3

Table I above lists various causes of demurrage on ships. The cause with the highest number of incidents was waiting for cargo barge (cargo barge not available) which occurred 26 times, with a significant increase in 2024 (21 incidents) compared to previous years. Waiting cargo barge (cargo barge was not yet available) occurred due to preloading activities of the previous mother ship and time arrival. Ships arriving simultaneously (overlapping time arrival) with occurred 22 times was recorded with one incidents in 2022, 3 incidents in 2023, and increase in 2024 to 18 incidents. Floating crane is not available because of not having completed servicing the previous vessel with occurred 19 times was recorded with one incidents in 2022, 5 incidents in 2023, and increase in 2024 to 13 incidents. In the incident queues due to loading priority for domestic ships recorded 12 incidents which also showed an increasing trend from 3 incidents in 2022, 2 incidents in 2023 to 7 incident in 2024.

Disruption of licensing procedures and administrative systems (Mining Operation Monitoring System/MOMS, verification results report/LHV, export notification of goods/PEB, Ship To Ship/STS) with occurred 8 times was recorded with no incidents in 2022, 3 incidents in 2023, and increase in 2024 to 5 incidents. Reduced coal supply with occurred 8 times was recorded with 4 incidents in 2022, 4 incidents in 2023, and no incident in 2024. Bad weather and high tides with occurred 6 times was recorded with no incidents in 2022, 1 incident in 2023, and 5 incidents in 2024. Floating crane is damaged or under maintenance with occurred 5 times was recorded with 2 incidents in 2022, 3 incidents in 2023, and no incident in 2024. Coal quality decline due to weather and sticky material due to rain and high humidity occurred 5 times recorded in 2024 alone. The last incident, target loading rate not achieved with occurred 3 times was recorded with 2 incidents in 2022, 1 incident in 2023, and no incident in 2024.

An analysis of historical coal export data at the Palembang dock revealed that the demurrage issue was not the result of a single factor, but rather an accumulation of multiple interconnected operational constraints. The most frequent causes of high ship demurrage between 2022 and 2024, ranked by frequency of occurrence, included: unavailability of cargo barges, simultaneous ship arrivals (overlapping arrival times), floating cranes being occupied with servicing other vessels, loading queues due to prioritization of domestic ships, disruptions in licensing and administrative procedures (Mining Operation Monitoring System/MOMS, verification results report/LHV, export notification of goods/PEB, Ship-to-Ship/STS operations), reduced coal supply, adverse weather and high tides, floating crane breakdowns or maintenance, deterioration in coal quality due to weather, sticky material caused by rain and high humidity, and failure to achieve the target loading rate. These findings, summarized in Table II, highlight 11 operational risks contributing to prolonged demurrage.

Calculating the Risk Priority Number (RPN)

Table III presents the total Risk Priority Number (RPN) scores for each operational risk. The data, obtained from 15 respondents, was compiled to determine the overall RPN score, which reflects the relative severity and potential impact of each identified risk. This comprehensive Failure Mode and Effects Analysis (FMEA) systematically identifies and quantifies the root causes of operational issues associated with high demurrage. The RPN for each risk was calculated by multiplying three factors Severity, Occurrence, and Detection. Higher RPN values signify critical operational risks that require urgent attention and targeted mitigation measures.

Table 2 List of Operational Risks

Code	Operational Risk Description
R1	Floating crane not available due to incomplete servicing of the previous vessel
R2	Disruption of licensing procedures and administrative systems (Mining Operation Monitoring System/MOMS, verification results report/LHV, export notification of goods/PEB, Ship-to-Ship/STS)
R3	Floating crane damaged or under maintenance
R4	Target loading rate not achieved
R5	Queues due to loading priority for domestic ships
R6	Decline in coal quality due to weather

Code	Operational Risk Description
R7	Adverse weather and high tides
R8	Sticky material caused by rain and high humidity
R9	Reduced coal supply
R10	Waiting for cargo barge (cargo barge not yet available)
R11	Simultaneous ship arrivals (overlapping arrival times)

Table 3 Total RPN Value

Code	Operational Risk Description	RPN
R1	Floating crane not available due to incomplete servicing of the previous vessel	228
R2	Disruption of licensing procedures and administrative systems (Mining Operation Monitoring System/MOMS, verification results report/LHV, export notification of goods/PEB, Ship-to-Ship/STS)	98
R3	Floating crane damaged or under maintenance	30
R4	Target loading rate not achieved	30
R5	Queues due to loading priority for domestic ships	105
R6	Decline in coal quality due to weather	24
R7	Adverse weather and high tides	21
R8	Sticky material caused by rain and high humidity	30
R9	Reduced coal supply	60
R10	Waiting for cargo barge (cargo barge not yet available)	432
R11	Simultaneous ship arrivals (overlapping arrival times)	294

Table 4 Risk Classification Based on Control Level

CODE	RISK	CONTROL LEVEL
R1	Waiting for cargo barge (cargo barge not yet available)	Controllable
R1	Ships arriving simultaneously (overlapping time arrival)	Controllable
R1	Floating crane is not available due to not having completed servicing the previous vessel	Controllable
R5	Queues due to loading priority for domestic ships	Controllable
R2	Disruption of licensing procedures and administrative systems (Mining Operation Monitoring System/MOMS, verification results report/LHV, export notification of goods/PEB, Ship To Ship/STS)	Uncontrollable
R9	Reduced coal supply	Uncontrollable
R8	Sticky material due to rain and high humidity	Uncontrollable
R3	Floating crane is damaged or under maintenance	Uncontrollable
R4	Target loading rate not achieved	Controllable
R6	Coal quality decreases due to weather	Uncontrollable
R7	Bad weather and high tides	Uncontrollable

The analysis indicates that waiting for a cargo barge (when the barge is not yet available) is the most critical risk, with a Risk Priority Number (RPN) of 432. This is followed by simultaneous ship arrivals (overlapping arrival times) with an RPN of 294, and floating crane unavailability due to incomplete servicing of a previous vessel with an RPN of 228. Other notable risks include loading queues caused by priority given to domestic ships (RPN 105), disruptions in licensing and administrative procedures including Mining Operation Monitoring System (MOMS), verification results report (LHV), export notification of goods (PEB), and Ship-to-Ship (STS) processes (RPN 98), and reduced coal supply (RPN 60). Risks with lower RPN values include sticky coal material due to rain and humidity (RPN 30), floating crane breakdowns or maintenance (RPN 30), failure to meet target loading rate (RPN 30), decline in coal quality due to weather (RPN 24), and adverse weather and high tides (RPN 21).

These risks are grouped into controllable and uncontrollable categories. Controllable risks include: waiting for a cargo barge, simultaneous ship arrivals, floating crane unavailability due to servicing delays, loading queues caused by domestic priority, and failure to meet target loading rates. The six uncontrollable risks are: disruptions in licensing/administrative systems, reduced coal supply, sticky coal material due to rain and humidity, floating crane damage or maintenance, coal quality degradation due to weather, and adverse weather/high tides. Many of the uncontrollable risks are linked to third-party operations or external factors beyond the company's direct control.

Root Cause Analysis (RCA)

While RPN-based risk assessment enabled prioritization of operational risks, deeper investigation was conducted using the 5 Whys method to determine root causes, focusing on controllable risks.

- Waiting for a cargo barge
  This issue stems from barges being unavailable or still serving other vessels, leading to queues. The problem is compounded by closely timed vessel arrivals to meet laycan schedules at the Palembang dock. Such scheduling conflicts could be mitigated through a dynamic vessel scheduling and rotation planning system based on real-time field conditions; however, no such system exists. Current coordination remains manual via monthly meetings, WhatsApp, email, or telephone and the available live CCTV tracking system is not integrated across units, preventing its use for real-time joint decision-making.
- Simultaneous ship arrivals
  This occurs due to a lack of centralized and integrated scheduling among shipping lines, causing multiple vessels to arrive when loading equipment (floating cranes and barges) is still occupied. Scheduling is currently guided primarily by laycan provisions in FOB contracts, without considering real-time operational factors like equipment availability or coal stock levels. Although an executive operational dashboard exists, it is underutilized due to high data variability, multiple unit involvement, and the complexity of maintaining consistent integration. Budget limitations, fragmented CCTV systems, bureaucratic decision-making, incomplete job descriptions, and poor inter-unit transparency further hinder coordination.
- Floating crane unavailability due to incomplete servicing
  Floating cranes at the Palembang pier are limited in number, and simultaneous ship arrivals often cause delays. Ongoing loading disruptions, slower-than-target loading speeds, and vendor-managed crane operations exacerbate the issue. Repairs or replacements take significant time, and poor synchronization between upstream coal supply and loading schedules worsens congestion. Limited information sharing between the company, crane vendors, and distribution units further reduces the ability to anticipate operational problems.

- Loading queues due to domestic priority
  Government regulations prioritize coal deliveries to domestic markets particularly for PLN power plants over exports. As per Ministry of Energy and Mineral Resources directives, domestic vessels are given loading priority, forcing export vessels to wait. The scarcity of barges and cranes prevents simultaneous servicing of domestic and export needs, especially during peak demand. Manual, unit-specific fleet management and the absence of a unified digital coordination platform hinder efficient allocation.
- Failure to meet target loading rates
  Delays occur during the mobilization of equipment and barges due to suboptimal performance of loading/unloading resources. Operational units focus heavily on achieving daily output targets, neglecting preventive maintenance. Loading performance monitoring is not conducted in real time across units, and CCTV feeds are restricted to individual divisions. Moreover, operational targets are rarely adjusted for actual conditions such as weather, stock availability, and equipment readiness, as management pressures persist for higher outputs regardless of field limitations.

Proposed Solution

Based on the results of a comprehensive Failure Mode and Effect Analysis (FMEA), and focusing on operational risks that remain within the company's control, the proposed solutions are strategically designed to address high-impact issues, thereby reducing operational risks and minimizing demurrage costs. Each solution directly targets the root causes of the controllable risks identified during the analysis. For the most critical risk waiting for a cargo barge (RPN 432)—the delays are primarily caused by barges being unavailable or occupied with other vessels, as well as the clustering of vessel arrivals to meet adjacent laycan schedules. The proposed measures include the digitalization of a simple barge rotation tracker using Google Sheets integrated with WhatsApp to monitor barge and vessel servicing status, combined with improved inter-unit coordination. To reduce queuing, an online form-based First Come, First Served (FCFS) scheme with laycan validation will be implemented to set loading priorities. Laycan scheduling will also be revised through negotiations with buyers to shorten scheduling windows. Furthermore, an integrated barge–vessel scheduling system connecting ports, distribution teams, and vessel vendors will be developed. Coordination will be enhanced through a digital collaboration platform and a shared dashboard that consolidates updates on vessel status, stock availability, and weather conditions.

The second priority risk simultaneous vessel arrivals (RPN 294) is attributed to the lack of integrated scheduling between distribution and port teams, as well as an overreliance on contractual laycan dates without real-time adjustment based on facility availability. To address this, an online ETA (Estimated Time of Arrival) confirmation system for shipping agents will be introduced, supplemented by daily spreadsheet updates that track equipment availability, floating crane queues, preload status, and stock conditions. These updates will be displayed on a shared operational platform. Decision-making will be streamlined through the use of shared KPIs and daily visual dashboards, reducing bureaucratic delays and fostering joint improvement initiatives across units.

For the third controllable risk floating crane unavailability due to incomplete servicing of a previous vessel (RPN 228) digital floating crane scheduling sheets will be introduced alongside daily allocation planning meetings. Real-time updates on loading performance will be implemented, along with integration between stock status and loading equipment readiness via daily check forms. Coordination with crane vendors will be formalized through MOUs and SLAs, and an online shared dashboard with vendors will improve transparency regarding crane condition, maintenance schedules, and operational availability. The fourth risk loading queues caused by domestic vessel priority (RPN 105) arises from government regulations prioritizing coal deliveries to national power plants. To mitigate this, barges and floating cranes will be segregated for domestic and export use, with dedicated time slots for export loading during peak demand. Real-time mapping of available equipment will be performed using Google Forms and Sheets, while a simple forecast-versus-actual demand dashboard will help optimize fleet allocation. Logistics planning will transition from manual coordination to a shared digital platform.

Finally, for the fifth controllable risk failure to achieve target loading rates (RPN 30) solutions include digitizing mobilization time tracking via Google Sheets, implementing a real-time dashboard comparing loading performance against SOPs, and conducting targeted training. Equipment maintenance schedules will be managed via Google Calendar, and CCTV monitoring will be integrated across units through IoT-enabled spreadsheet displays. Management expectations will be aligned with operational realities using data-driven tracking tools. By systematically implementing these solutions, PT CMC can significantly reduce demurrage, enhance operational efficiency, and strengthen service delivery. These measures not only align with FMEA principles but also bridge the gap between current operational constraints and the desired future state through targeted, technology-enabled process improvements.

Table 5 Phase I Implementation

No.	Activity	PIC	Schedule
1	Create an online Google Sheet/Spreadsheet containing daily manually updated barge/floating crane rotations and share it across all units by WhatsApp	Pier operational team and Distribution team	Q1 (M1)
2	Create a special Google Form for filling in ETA (Estimated Time of Arrival), laycan, and ship position which is filled in by the agent 2 or 1 day before arrival	Pier operational team	Q1 (M1)
3	Create a Google Sheet containing loading status, stock, preload status	Palembang pier team, coal transportation handling team	Q1 (M1–M2)
4	Create a Google Sheet containing: daily targets, actuals, main obstacles (manual input weekly)	Distribution team, Palembang pier team, coal transportation handling team, distribution team	Q1 (M2–M3)

Table 6 Phase Ii Implementation

No.	Activity	PIC	Schedule
1	Propose shortening the laycan schedule	Pier Operations Supervisor	Q2–Q3 (M4–M9)
2	Jointly determine KPIs: Waiting time, Floating crane utilization, ETA (Estimated Time of Arrival) accuracy; share loading performance via TV screen/file	Operational Manager, Distribution Supervisor, Port PIC	Q2–Q3 (M4–M9)
3	Create a digital spreadsheet for operational status, downtime, and maintenance plans	Palembang pier team, Coal transportation handling team, FC vendor	Q2–Q3 (M4–M9)
4	Allocate at least 1 floating crane/barge for export on specific days/dates based on demand forecast	Palembang pier team, Coal transportation handling team	Q2 (M4–M6)

No.	Activity	PIC	Schedule
5	Implement daily time window allocation for floating crane exports	Palembang pier team, Coal transportation handling team	Q2–Q3 (M4–M9)
6	Create a Google Sheet dashboard with visualizations (projected demand vs daily floating crane/barge capacity)	Distribution team	Q2–Q3 (M4–M9)
7	Develop one integrated spreadsheet for all units (ship ETA, loading status, available floating cranes/barges) with coordination via Google Chat/WhatsApp Group	Palembang pier team, Coal transportation handling team, Distribution team	Q2–Q3 (M4–M9)
8	Use a shared Google Calendar for weekly routine maintenance schedules with vendor	Palembang pier team, Coal transportation handling team	Q2–Q3 (M4–M9)
9	Synchronize CCTV links from each unit into a single dashboard (Google Sheet or Spreadsheet)	IT, Palembang pier team, Coal transportation handling team	Q2–Q3 (M4–M9)
10	Create a Google Sheet for loading progress status updates every 2 hours	Pier Operations Supervisor	Q2–Q3 (M4–M9)
11	Develop a digital form for equipment status, preload, and stock (checklist by operator and stock officer every morning)	Palembang pier team, Coal transportation handling team	Q2–Q3 (M4–M9)
12	Google Form to be filled in by operators every 2 days (floating crane/barge condition and actual location), with automatic updates to Google Sheet	Palembang pier team, Coal transportation handling team, Distribution team	Q2–Q3 (M4–M9)

Table 8 Phase Iii Implementation

No.	Activity	PIC	Schedule
1	The revised floating crane vendor SLA (Service Level Agreement) requires that a replacement floating crane be available within ≤12 hours or that backup equipment be provided during unplanned downtime.	Pier Operations Supervisor	Ongoing from Q4
2	Install sensors/IoT devices or update digital/manual logs on loading equipment.	IT, Palembang Pier Team, and Coal Transportation Handling Team	Q4 (M10–M12)

DISCUSSION

The application of Failure Mode and Effect Analysis (FMEA) in managing demurrage at the coal mining corporation has provided valuable insights into identifying, prioritizing, and mitigating operational inefficiencies that contribute to vessel delays. The results indicate that demurrage incidents are primarily caused by equipment breakdowns, unplanned downtime of floating cranes, inefficient loading operations, and communication gaps between distribution, pier, and transportation handling teams. By systematically analyzing each potential failure mode, assigning Risk Priority Numbers (RPN), and ranking them based on severity, occurrence, and detectability, the company has been able to focus its resources on the most critical operational bottlenecks. Key improvements identified through this study include revising the Service Level Agreement (SLA) with floating crane vendors to ensure rapid replacement or backup availability, implementing IoT-based monitoring systems for real-time equipment performance tracking, and enhancing coordination between operational units through standardized reporting mechanisms. These actions directly address high-RPN failure modes and are expected to significantly reduce vessel waiting times, thereby minimizing demurrage costs.

Furthermore, the integration of FMEA into the company's operational management framework has demonstrated its effectiveness as a preventive tool, enabling proactive risk mitigation rather than reactive problem-solving. While the case study focuses on a single coal mining corporation in Indonesia, the methodology and findings are applicable to similar bulk cargo operations, particularly in developing economies where infrastructure and operational challenges are prevalent. However, it should be noted that the success of FMEA implementation depends on accurate data collection, consistent monitoring, and commitment from all stakeholders. Limitations such as data gaps, variability in operational conditions, and potential resistance to procedural changes may influence the long-term effectiveness of the recommendations. Future research may expand this approach by integrating predictive analytics and simulation models to enhance decision-making in demurrage management.

CONCLUSION

1. The analysis revealed that demurrage primarily arises from various operational risks.Controllable risks include delays in cargo barge availability (Cargo Barge Not Yet Available) (RPN 432), simultaneous vessel arrivals causing schedule overlaps (RPN 294), unavailability of floating cranes due to ongoing servicing of previous vessels (RPN 228), loading queues caused by prioritization of domestic ships (RPN 105), and failure to achieve the target loading rate (RPN 30). Conversely, uncontrollable risks comprise disruptions in licensing and administrative processes (such as the Mining Operation Monitoring System/MOMS, verification results report/LHV, export goods notification/PEB, and Ship-to-Ship/STS operations) (RPN 98), floating crane breakdowns or maintenance (RPN 30), coal quality deterioration due to adverse weather conditions (RPN 24), bad weather and high tides (RPN 21), sticky material caused by rain and high humidity (RPN 30), and reduced coal supply (RPN 60).
2. Root cause Analysis risk of:
   waiting for cargo barge (cargo barge not yet available) is:
   - The scheduled cargo barge is not yet available or is still serving another vessel: digitalization of simple barge rotation tracker (Google Sheet + WhatsApp Integration) to monitor the status of barges and ships being serviced and improved coordination between units.
   - There is a queue of ships at the dock and the rotation of the barges must be adjusted to the ships that arrive according to schedule: solution digitalization with the implementation of an Online Form-Based FCFS Scheme with laycan validation to determine loading priorities (FCFS stands for First Come (as appropriate to the laycan).
   - Many ships arrive almost simultaneously to meet the schedule of adjacent laycans: revise the implementation of the laycan schedule through negotiations with buyers and shortening the laycan schedule.
   - A digital barge scheduling system is not yet available. There is no dynamic, real-time vessel rotation system with proposed solution: implementing an Integrated Barge-Vessel Scheduling System, An integrated system between ports, distribution, and ship vendors.

- Coordination between operational units is ineffective and is still conducted manually (monthly meetings, communication via WhatsApp/email/phone). Currently, only a live CCTV tracking system is available, but it is not yet corporately connected, making it unusable across units as a platform for shared decision-making: improved coordination between units and Digital Collaboration Platform, Shared dashboard (across units) for updates on vessel status, stocks, weather, etc. (like a shared online spreadsheet platform).

Ships Arriving Simultaneously (Overlapping Time Arrival) is:

- Ship arrival schedules are not comprehensively regulated and coordinated between shipments so that ships arrive at almost the same time (lack of coordination between distribution team and port team): Digitalization of Online Forms and ETA (Estimated Time of Arrival) Confirmation by Shipping Agents
- Ship Time Arrival planning still focuses on the laycan contract with the buyer (FOB/Free On Board), without dynamically considering the availability of loading facilities (floating crane/barge) and the progress of previous ship loading in the field: Digitization with daily spreadsheet updates
- There is no real-time data-based prediction and monitoring system that informs field capacity and potential delays, such as floating crane queues, preload status, and stock conditions: Google Sheet dashboard digitization floating crane integration, loading Status, stock, and weather
- Coordination between operational units is not yet effective and is still carried out manually (monthly meetings, communication via WhatsApp/email/telephone) without an integrated digital platform: Shared Operational Digital Platform (like spreadsheet)
- The decision-making process is still hierarchical and bureaucratic, work units are often not open to real-time data, job descriptions have been written but are not detailed, each work unit feels that what they have done is optimal so that there are no joint improvement initiatives across units: Shared KPI & Visual Dashboard Daily Progress (load, waiting time, floating crane use)

Floating crane is not available due to not having completed servicing the previous vessel is:

- Loading facilities (Floating Crane/FC) are only available in limited quantities and ships arrive together: Digital floating crane scheduling sheet and floating crane allocation planning meeting (Daily)
- The previous ship loading process was not completed due to delays and operational disruptions: Digitalization for Daily Real-Time Loading Performance updates
- The previous ship loading process was not completed due to delays and operational disruptions: Digitalization for Daily Real-Time Loading Performance updates
- The actual loading rate was lower than the target due to equipment failure and less than ideal coal stock conditions: Stock status and loading tool integration (via daily check form) and coordination with cross-units
- Floating crane are managed by external vendors whose management isn't fully under internal control, and when the primary floating crane breaks down, the process of bringing in a replacement floating crane takes time. Furthermore, coal supplies from upstream don't sync with ship loading schedules: MOU (Memorandum of Understanding), SLA (Service Level Agreement) with floating crane & alert system vendor
- Floating crane management is under a third party so that the transparency of information regarding the condition and maintenance schedule is not fully known internally and there is no adequate data coordination and integration system between the company and the floating crane vendor: Shared Dashboard online with vendor floating crane

Queues due to loading priority for domestic ships is:

- Through a Circular Letter from the Ministry of Energy and Mineral Resources to prioritize coal deliveries to national power plants (PLN): Segregate domestic and export-specific barges/floating crane based on demand
- Loading facilities (barges and floating cranes) are also limited so that almost all capacity is initially allocated to domestic needs first: floating crane and barges for export are dedicated to certain time slots (window sharing)
- The number of available barges and floating crane is insufficient for simultaneous dual needs, especially during peak season: Latest floating crane /barge mapping (via Google Form and Sheet)
- There is no fleet rotation and allocation system based on real-time demand projections and coordinated across units: Simple Dashboard of Forecast vs Actual Demand
- Inter-unit logistics planning is still done manually and is not yet based on a shared digital platform: Shared operational digital platform (like spreadsheet)

➢ Target Loading Rate Not Achieved is:

- There is a mobilization time which causes a time lag during the transition of equipment or barges: Digitization by Google Sheet
- The available loading and unloading equipment or human resources are not working optimally according to operational standards: Loading Realization Dashboard versus SOP/ Standard Operating Procedure (real-time tracking) and data-based training
- In practice, units are more focused on achieving daily targets so that routine equipment maintenance is sometimes neglected: Digitalization by Google Calendar
- The CCTV monitoring system is only available and used by each unit, it is not integrated with other units: Digitalization by integrating CCTV displays with spreadsheets through an iot platform
- There is pressure to achieve increased targets from management without considering actual operational limitations in the field: Google Sheet-based digitalization.

LIMITATION

A limitation of this study is that the FMEA analysis was conducted based on a single case study within one coal mining corporation in Indonesia, which may limit the generalizability of the findings to other industries or operational contexts.

Recommendations

The implementation plan for the proposed business solutions should adopt a phased and prioritized approach, with priorities determined based on the FMEA and RPN scores to ensure optimal impact. The first step is to address the highest-priority issues, particularly those related to barge resource allocation. For example, creating an online Google Sheet with daily updates on barge availability, and developing a dedicated Google Form for recording estimated times of arrival, laycan schedules, and vessel positions, to be completed by the appointed agent one to two days before arrival. Beyond prioritization, the execution of these solutions should follow a systematic approach, ensuring consistent application across all operational areas involved. This process requires strong cross-functional collaboration among the dock, distribution, and transportation handling teams to achieve integrated and effective results. The phased strategy consists of three stages: Phase 1 focuses on immediate and high-impact actions; Phase 2 targets medium-term improvements to enhance sustainability; and Phase 3 aims at fostering a long-term cultural shift. Detailed implementation steps, along with the designated Persons in Charge (PICs), are outlined in Tables I–VII The proposed timeline serves as a guideline and may be adjusted according to the organization’s specific resources and operational requirements.

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