Cycle Time Optimization of Coal Hauling from SWA Block to ROM Aster Using Six Sigma DMAIC Approach

A Case Study at PT XYZ Mining Company, Central Kalimantan, Indonesia

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Abstract: This research analyzes the delay in coal transportation cycle time from SWA Block to ROM Aster at PT XYZ using the Six Sigma DMAIC approach. The average actual cycle time reached 6.46 hours, compared to the planned 3.62 hours. This deviation was caused by a combination of factors: human (lack of supervision and driver training), machine (availability below 90% and frequent tire issues), method (slow loading and queue delays), material (unavailable coal stock), and environment (non-AWR roads and narrow slopes). The research method involved observation, in-depth interviews, and document analysis. Root cause analysis was conducted using a Fishbone Diagram and NVivo qualitative tools. The DMAIC model was applied to define, measure, analyze, improve, and control the process. Improvements proposed include widening roads, increasing night-shift supervision, training drivers, and integrating stock monitoring systems. The findings highlight systemic operational inefficiencies and offer structured corrective actions for sustainable hauling performance.

Keywords: *Cycle Time; Coal Hauling; Fishbone Diagram; Six Sigma; DMAIC.*

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I. INTRODUCTION

A. Background of the problem

PT XYZ is a coal mining company that operates using an open pit mining method, which relies heavily on the efficiency of the coal transportation process from the mine site to the processing facility. One of the critical paths is the hauling segment from the SWA Block to the ROM Aster, a distance of approximately 54.34 km. However, in its implementation, there is a discrepancy between the actual cycle time (average 6.46 hours) and the set target (3.62 hours). This indicates a significant inefficiency and has a direct impact on the failure to achieve production targets. This time gap indicates a systemic obstacle in the coal transportation process, which needs to be thoroughly identified. Structured improvement efforts are needed so that the hauling process can run optimally, effectively, and efficiently according to company planning.

B. Impact of Cycle Time Mismatch

Cycle time inconsistencies have a significant impact on PT XYZ's daily production. Data shows that shift 2 (night) consistently produces lower transport volumes than shift 1 (day), even though the average load capacity per unit is nearly equivalent. This difference is caused by the small number of units operating at night and the long travel time caused by delays in the transport cycle. In addition to reducing delivery volumes, delays also affect the availability of coal stocks at ROM Aster and hamper the smooth running of subsequent production processes. In the long term, this condition risks creating a delivery backlog, reducing heavy equipment utilization, and impacting customer satisfaction and overall business continuity.

C. Formulation of the problem

Coal transportation from the SWA Block to the ROM Aster at PT XYZ experienced a significant time deviation between the actual and planned cycle times. The target transportation time of 3.62 hours was not achieved, with the actual average reaching 6.46 hours. This discrepancy impacted the failure to achieve daily production volume, especially in the 2nd (night) shift, which only recorded around 66% of the transportation volume compared to the 1st shift. Operational data showed that although the loading capacity per unit was relatively the same, the number of units and the effectiveness of night operations were lower.

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This raises questions about the root causes of the delay, both in terms of people, equipment, work methods, road conditions, and material availability.

Based on this background, this study is designed to answer several key questions: First, what are the main causes of delays in the cycle time of coal transportation from the SWA Block to the ROM Aster? Second, how does this delay impact the production imbalance between shift 1 and shift 2? Third, how can operational improvement steps be formulated systematically using the Six Sigma (DMAIC) approach to increase the efficiency and effectiveness of the hauling process? These three problem formulations serve as the basis for analysis to identify root causes, measure impacts, and design sustainable solutions within the operational scope of PT XYZ's hauling operations.

II. LITERATURE REVIEW

A. Cycle Time Theory

Cycle time is a key indicator for measuring the efficiency of transportation processes in the mining industry. Scholz-Reiter et al. (2011) stated that cycle time encompasses the total time from loading to unloading, including travel time, queues, and other supporting activities. Himawan et al. (2020) emphasized the importance of controlling cycle time variance to maintain the stability of open-pit mining transportation systems. Sepriadi (2018) suggested optimization through road widening and improving front loading access to speed up the trip. In addition to technical aspects, Yuniar et al. (2020) added that driver behavior is also a crucial variable, as driving decisions affect operational speed and safety. Good cycle time efficiency not only reduces operational costs but also contributes to reducing carbon emissions as part of a company's sustainability strategy (Yuniar et al., 2020; Himawan et al., 2020).

B. Fishbone Diagram Theory

The Fishbone Diagram, or Cause and Effect Diagram, was first developed by Kaoru Ishikawa in 1943 as a tool to identify the root cause of a problem. According to Wirtz (2017), this diagram is used to group causal factors into several main categories such as man, method, machine, material, and environment. In the mining context, fishbone diagrams help operational teams systematically brainstorm to identify the causes of cycle time delays, such as unit failures, road conditions, or weaknesses in shift management. Cahyati et al. (2024) in their research also used fishbone diagrams to trace the causes of machine failures before developing a preventive repair program, proving the effectiveness of this tool in both technical and managerial contexts (Cahyati et al., 2024; Wirtz, 2017).

C. Six Sigma DMAIC Theory

Six Sigma is a data-driven quality management approach aimed at reducing process variability and improving operational performance. The DMAIC (Define, Measure, Analyze, Improve, Control) model is a structural step in Six Sigma for solving problems and continuously improving processes. Trubetskaya et al. (2023) demonstrated the successful implementation of DMAIC in the dairy industry by reducing shutdown duration from 11 weeks to 7 weeks. In Indonesia, Wiguna (2022) successfully applied DMAIC to reduce production defects and improve manufacturing process efficiency. In the mining industry, this method is relevant for analyzing cycle time delays by precisely defining the problem, measuring time deviations, analyzing root causes, designing technical and managerial solutions, and implementing continuous control. DMAIC also reinforces the principle of continuous improvement, which is essential for supply chain-based industries (Trubetskaya et al., 2023; Wiguna, 2022).

III. METHODOLOGY

A. Research methods

This research uses a qualitative approach with a descriptive exploratory method. The descriptive approach aims to systematically describe the actual conditions in the field, particularly regarding cycle time delays in the coal transportation process at PT XYZ. The exploratory approach is used to identify key variables uncovered in previous studies and provide an in-depth understanding of the delay phenomenon. The primary focus is on operational causes and relevant improvement strategies for direct application in the hauling process.

The research paradigm used is an interpretive paradigm, which prioritizes understanding social interactions, work systems, and technology in the context of coal transportation. A case study research design was chosen to explore one specific case, namely the deviation of cycle time from the plan that occurred on the hauling route from the SWA Block to the ROM Aster. The researcher acted as the primary instrument, directly observing operational activities and interviewing key informants to obtain accurate and relevant contextual data.

B. Data collection technique

Data collection techniques included direct observation of hauling activities, in-depth interviews with dump truck drivers, operational supervisors, and field personnel, as well as daily and monthly company operational documentation. Observations were conducted to record the actual times of loading, traveling, dumping, and weighing processes. Semi-structured interviews were conducted to obtain exploratory data from operational actors. Documentation was used to verify field data with the company's historical data. Data validity was strengthened through triangulation of sources, methods, and theories.

C. Research Flow

The research process began with problem identification, specifically the delay in actual cycle time compared to the planned one. Data collection was then conducted through observation, interviews, and documentation. The collected data was then reduced and categorized based on five main factors: man, machine, method, material, and environment. Analysis was conducted using a Fishbone Diagram to trace the root cause of the problem. Next, a DMAIC approach was used: Define to

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formulate the main problem, Measure to measure actual performance, Analyze to analyze the root cause, Improve to design operational solutions, and Control to build a continuous cycle time control and monitoring system.

IV. DISCUSSION RESULTS

A. Observation Results

Direct observation of the coal transportation process from the SWA Block to the Aster ROM shows that the average actual cycle time is 6.5 hours, exceeding the planned target of 3.62 hours. Observations of refueling, loading, traveling, weighing, dumping, and queuing activities indicate that most of the wasted time occurs in the traveling, loading queues, and refueling processes. Detailed observation data can be seen in Table 4.1, which shows the results of a random test of dump truck cycle time activities. In addition, Figure 4.2 displays a graph of the average cycle time during February 2025, illustrating the high deviation of cycle time compared to the plan.

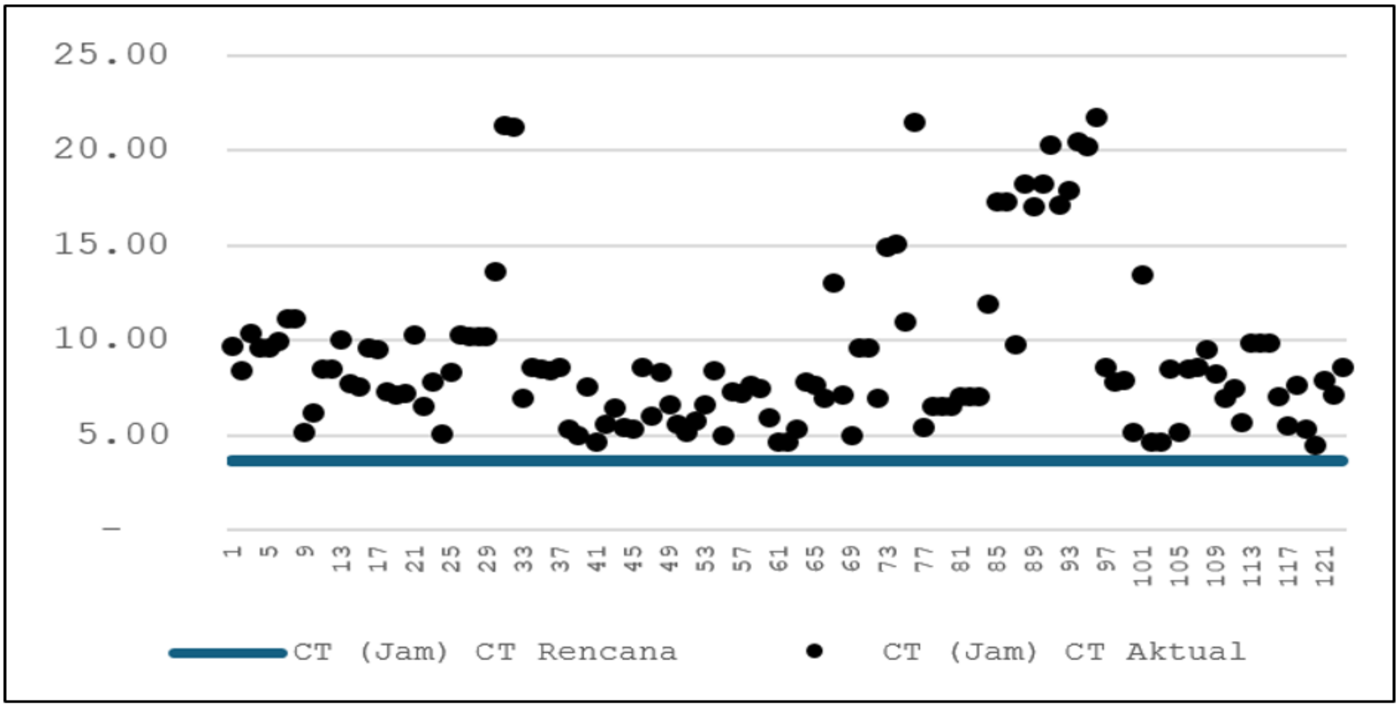

Fig 1 Scatter Cycle Time Diagram for Shift 1 in February 2025

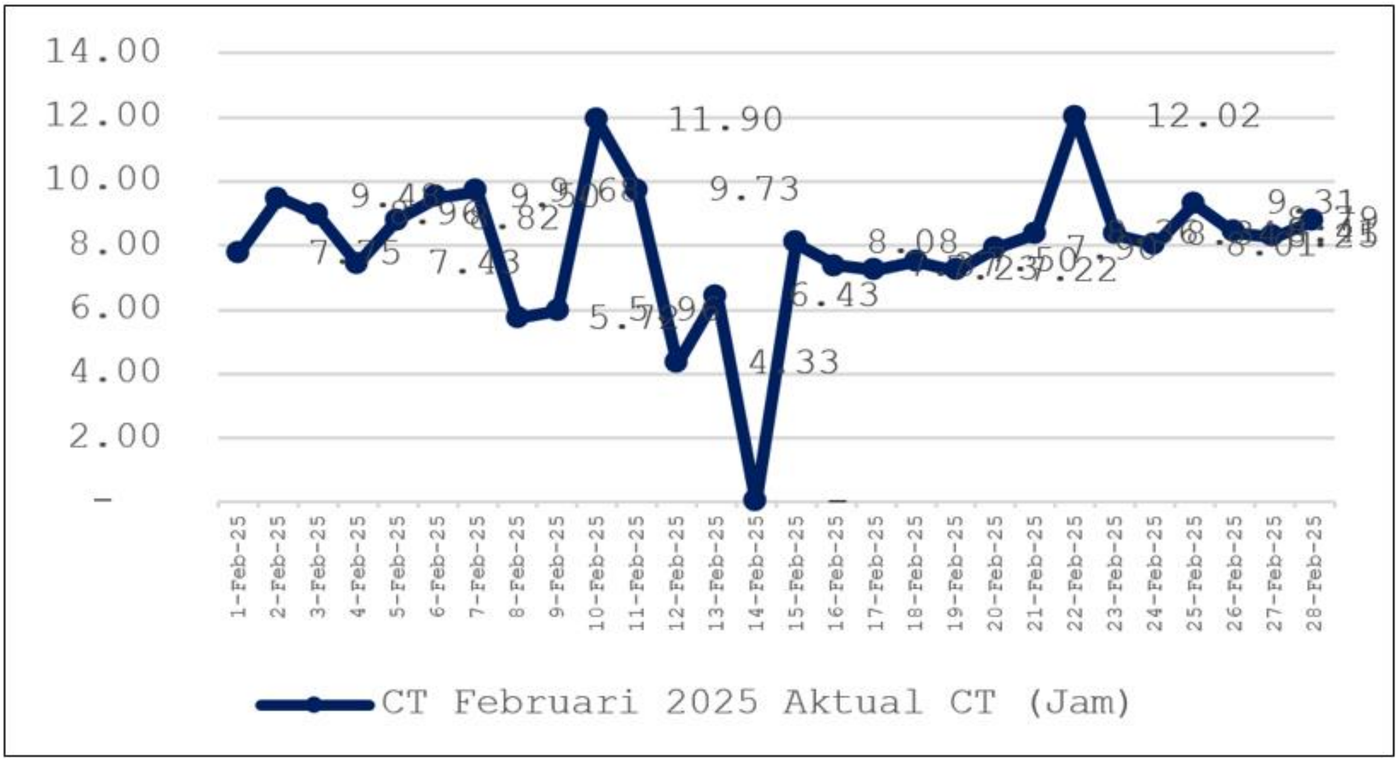

Fig 2 Average Cycle Time Graph for February 2025

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B. Interview Results

Interviews with operators, supervisors, and field managers revealed that a major obstacle is the lack of coal stock when units arrive at the front loading area, leading to queues and idle time. Other factors include inadequate road conditions, such as narrow roads and steep inclines, and a lack of communication between departments, particularly between hauling and production.

Interviews also revealed that loading equipment is frequently used for coal collection, slowing down the loading process. Suboptimal equipment conditions and a lack of real-time coordination between supervisors on different shifts exacerbate delays. These factors directly impact cycle times.

Feedback from drivers and supervisors indicates that a lack of hauling field training, limited communication equipment, and a shortage of supervisors on the night shift significantly contribute to cycle times. This situation creates a shift imbalance, with the first shift being more productive than the second.

C. Analysis Results

The analysis was conducted using a Fishbone Diagram approach to identify the main root causes of cycle time delays. This diagram groups the causes into five categories: Man, Machine, Material, Method, and Environment. Based on NVivo analysis, the dominant words appearing in the interviews were 'road,' 'loading,' 'stock,' and 'queue.'

Table 4.3 details the causes of each factor. For example, on the Human Resources side, issues with driver and supervisor competency were identified, leading to delayed decision-making. On the Machine side, unit physical availability (PA) was below 90% due to tire damage and a lack of preventive maintenance. Unstandardized work methods and poor shift coordination also played significant roles.

Environmental analysis showed that the road was not yet AWR, had a grade above 12%, and was not up to standard, contributing to the delay. On the materials side, delays occurred because coal stocks were not ready for loading, resulting in queues and standby times.

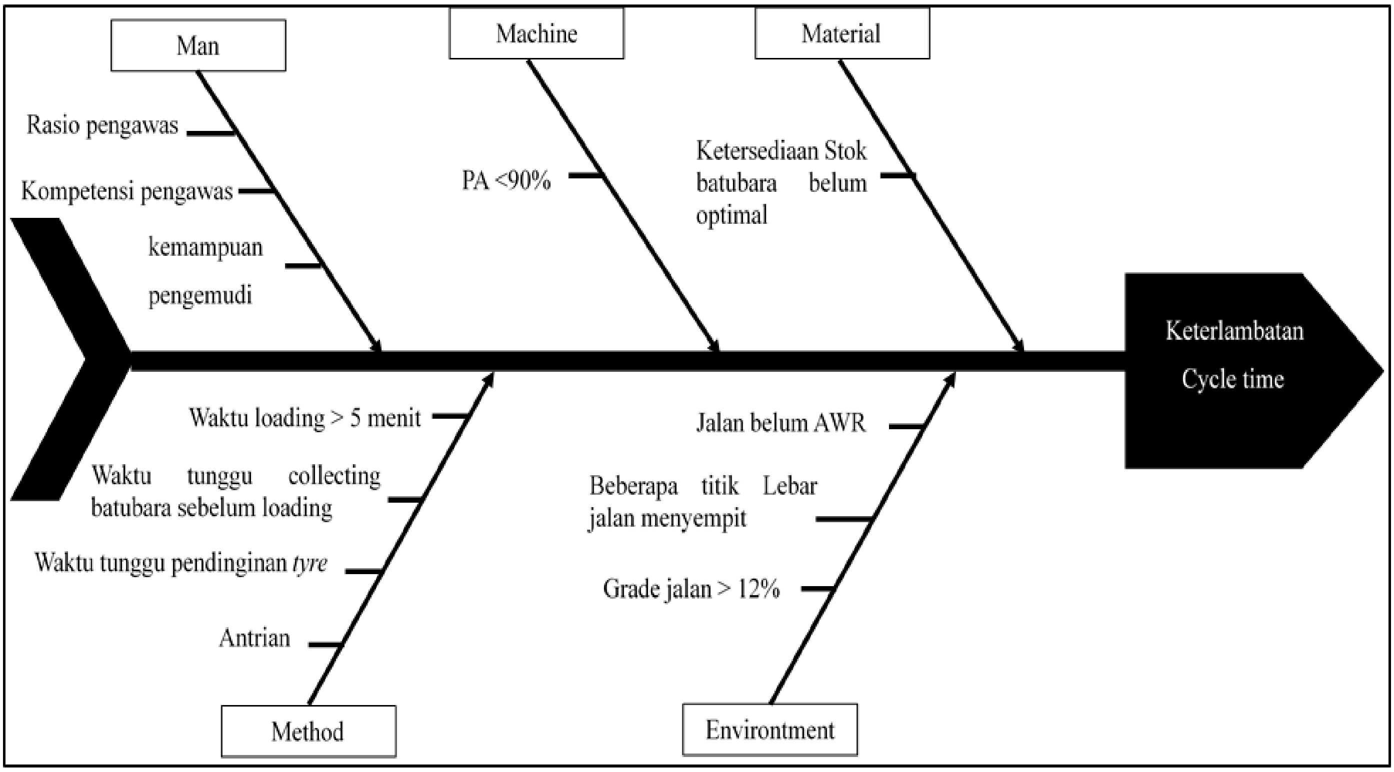

Fig 3 Fishbone Diagram of Cycle Time Delay

D. Improvement Steps with the DMAIC Approach

The Six Sigma approach with the DMAIC method was applied in this study to formulate systematic improvement solutions. The Define stage determined that the primary problem was the deviation of actual cycle time from the plan. In the Measure stage, cycle time data was collected from direct observations and scale reports.

The Analyze phase was conducted using Fishbone diagrams and NVivo data processing to identify root causes. The Improve phase yielded several solutions, including: increased road maintenance, widening bends, improving inter-shift communication, adding a second-shift supervisor, integrating the coal inventory system, and upgrading loading equipment.

The Control phase is structured by developing daily cycle time achievement indicators, weekly loading time observations, and shift communication evaluations through pre-shift meetings. These improvement steps ensure that cycle time reductions can be maintained sustainably and measurably.

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V. DISCUSSION

A. Causes of Cycle Time Delays Based on Fishbone Diagram

The analysis of the causes of cycle time delays was conducted using a Fishbone Diagram, also known as the Cause and Effect Diagram. This structured visual tool identifies five primary factors influencing delays: Man, Machine, Method, Material, and Environment (Cahyati et al., 2024). In the *Man* factor, driver competence was found to be suboptimal, and the supervisor-to-driver ratio was unbalanced, particularly during night shifts (Wiguna, 2022). Regarding *Machine*, periodic tyre damage on dump trucks and Physical Availability (PA) below 90% were frequently reported issues, affecting operational continuity (Trubetskaya et al., 2023). The *Method* factor highlighted inefficiencies, particularly extended loading times due to waiting for coal stockpiles to be prepared (Yuniar et al., 2020). From the *Material* side, unavailability of coal at the loading point significantly impacted haulage readiness. Lastly, *Environmental* constraints such as narrow roads, steep grades, and routes not meeting All Weather Road (AWR) standards further exacerbated delays (Scholz-Reiter et al., 2011). These findings underscore the interconnected nature of systemic issues in mining logistics and the need for integrated improvement initiatives.

B. Impact of Cycle Time Delay on Production in Shift 1 and Shift 2

Cycle time delays directly impact production volume imbalances between shift 1 and shift 2. Observational data indicate that shift 2 consistently transports only about 66% of the volume achieved during shift 1. This discrepancy stems from extended travel times, limited operational dump truck units during night hours, and inadequate supervision and lighting along the hauling route (Setiawan et al., 2023). Such disparity leads to suboptimal daily production distribution, disrupting material stock planning at ROM Aster. Additionally, coal backlogs accumulate at the mining front due to delayed transportation in shift 2, adversely affecting the continuity of the mining process and the downstream supply chain (Pratama & Yuliani, 2022). These findings align with the study of Nugroho et al. (2021), who reported that inadequate shift-based hauling performance can significantly degrade operational efficiency and delay scheduled shipments to customers.

C. Steps to Improve Cycle Time with the Six Sigma DMAIC Approach

To systematically address cycle time delays, this study employed the Six Sigma approach through the DMAIC (Define, Measure, Analyse, Improve, Control) methodology. During the *Define* stage, the primary issue was identified as the deviation between actual and planned cycle time targets. The *Measure* phase included data collection on trip duration, travel time, and queue intervals sourced from scale logs and direct field observation (Hendrawan & Yusuf, 2021). At the *Analyse* stage, root cause analysis was conducted using a Fishbone Diagram and NVivo software, allowing categorisation of problems under Man, Machine, Method, Material, and Environment (Siregar et al., 2022). In the *Improve* stage, practical interventions were proposed, such as widening curved road segments, enhancing communication systems across shifts, driver competency training, and real-time synchronisation of coal stock availability. Finally, the *Control* phase was established through cycle time monitoring indicators, weekly shift evaluations, and pre-shift coordination meetings aimed at sustaining improvements (Putra & Dewi, 2023). This structured approach ensures that each problem area is addressed using data-driven decision-making and continuous feedback.

VI. CONCLUSION AND DISCUSSION

A. Conclusion

This study concluded that the delay in coal transportation cycle time from the SWA Block to the ROM Aster at PT XYZ was caused by Man, Machine, Method, Material, and Environment factors. The actual cycle time reached 6.5 hours compared to the planned 3.62 hours. Observation and interview results indicated that the delay was caused by the road not being AWR, stock not being available, and weak coordination between shifts. The Fishbone Diagram approach helped identify the root cause, while Six Sigma DMAIC was used to develop corrective measures. Recommendations included road widening, driver training, adding night shift supervisors, and stock system integration.

B. Discussion

The results of this study align with those of Trubetskaya et al. (2023) and Wiguna (2022), which demonstrated the effectiveness of DMAIC in reducing process time and operational variation. Fishbone diagrams have been shown to be effective in systematically grouping root causes (Cahyati et al., 2024), while the role of drivers and shift supervision is supported by the findings of Yuniar et al. (2020). This approach provides practical contributions to logistics planning and operational improvement of hauling in the mining industry.

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