OPTIMIZATION OF THE COAL HANDLING FACILITY LINE FOR COAL SUPPLY TO A COAL-FIRED POWER PLANT

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ABSTRACT

The Coal Handling Facility (CHF) functions as the principal conveyor line responsible for delivering coal to the coal-fired power plant. Coal extracted from the mining face is transported by dump trucks over an average distance of approximately five kilometers before being transferred to the conveyor system, which subsequently channels the coal to the power plant. In parallel, overburden materials are transported to designated disposal sites located about four kilometers from the mining area. These operational conditions underscore the necessity of optimizing the CHF route to enhance overall system efficiency. This study investigates the operational constraints and develops strategies for improving coal supply chain performance to the power plant. The research employs the Six Sigma methodology, utilizing its structured problem-solving framework : Define, Measure, Analyze, Improve, and Control (DMAIC), to propose optimization measures aimed at enhancing efficiency and reducing operational costs for the company.

Keywords*: Coal Handling Facility (CHF); Coal fired Power Plant; Conveyor; Six Sigma; Cost Reduction; Define, Measure, Analyze, Improve, and Control (DMAIC)*

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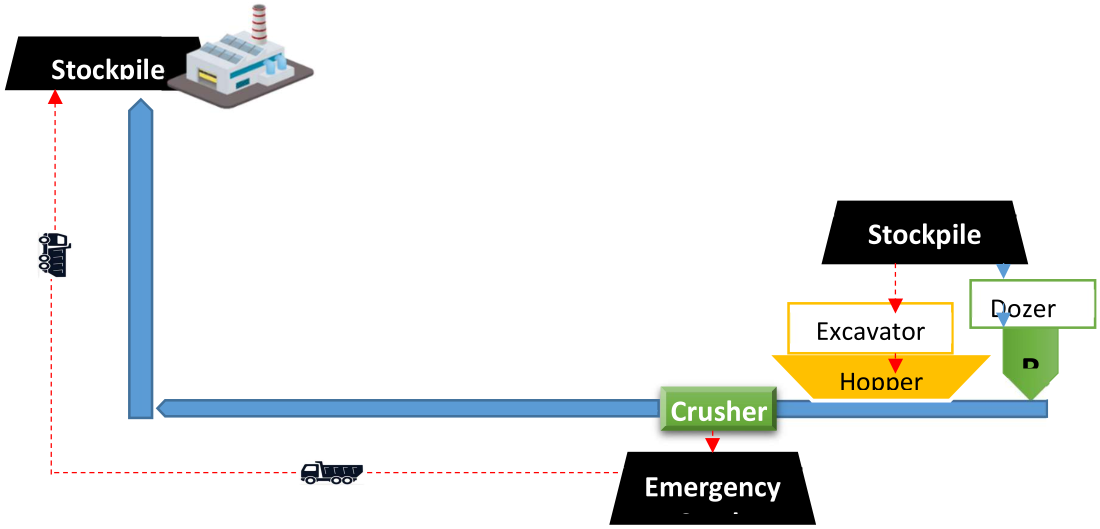
INTRODUCTION

PT XYZ is one of Indonesia's leading coal mining companies with a long history dating back to the Dutch colonial era over the decades. Its primary mining operations are located in Tanjung Enim, South Sumatra. They are supported by strategic infrastructure, including railways and ports, facilitating efficient coal delivery to domestic and international markets. In recent years, PT XYZ has consistently increased coal production. Leveraging vast reserves and improved mining technology, the company has achieved a steady year-on-year growth in output, supplying both low and high-calorie coal types to meet varying market demands. PT XYZ's production strategy emphasizes volume and quality, with efforts to increase the share of high-calorific value coal to serve premium market segments. The company's ability to scale production while maintaining operational safety and sustainability standards has been central to its continued competitiveness in the global coal market.

The increase in global coal production and changes in coal-based energy usage policies in several consumer countries mean that coal prices continue to decline. The imbalance between high production levels and slowing consumption in major consumer countries has resulted in an oversupply, exerting downward pressure on coal prices in international markets (Lie et al. 2024). Meanwhile, the world's increasingly limited fuel oil-based energy sources are inversely proportional to the increasing demand for fuel and have resulted in the tendency for fuel prices to continue to increase so that high production costs in the economic sector cannot be avoided. Oil price volatility caused by supply–demand imbalances adversely affects the economic performance of both oil-exporting and oil-importing countries (Agboola, 2024). The company has responded quickly to these conditions by increasing operational efficiency, controlling costs, and diversifying export marketing, including introducing focused mining patterns. The company also focuses on marketing coal with higher calories, which has a better selling price, to maintain margins amidst falling prices, considering that production costs remain the same.

Operational efficiency and cost control programs implemented consistently have succeeded in controlling the increase in production costs per ton of coal, but this has not been able to compensate for the uncontrollable decline in the average selling price of coal. One of the operational efficiency programs to optimize cost control and company development is to improve the conventional fuel-based Dump Truck mining system and use heavy equipment to become electrification-based by optimizing internal resources in the form of electricity-based Conveyor equipment and Main Mining Tools.

CHF is the main coal supply conveyor line to the fired power plant, where the coal supply to the power plant is operational, with an average coal usage of 2100 per day and 700.000 per year. Along with mining development and guaranteeing coal supply to the Power Plant, there are several challenges, namely, Production and Operations are not yet optimal, where the mining front has moved closer to the Power plant, so if you maintain the position of the existing reclaim feeder, it will increase trucking costs from the front towards the conveyor line. Reliability of equipment for supplying coal to Power plant using a conveyor system. With a conveyor system that is 5 KM away, when there is an obstacle that has the potential to disrupt coal supply to the power plant, the grain size of coal for supply must be kept at 50 mm. Rainy conditions are one of the obstacles to operations from the front, which cannot be carried out due to dump truck safety factors. Performance of heavy equipment for support production. To solve this challenge, a very effective breakthrough is needed to optimize the current system. The operational scheme for the CHF supply line to the Power Plant is as follows :



Source : Internal data Company PT XYZ, 2024

Figure 1
Flowchart of coal supply to the Power Plant

The CHF is the main conveyor line supplying coal to the power plant. Currently, the mining front has moved closer to the power plant, so maintaining the position of the existing reclaim feeder will increase trucking costs from the mining front.

LITERATURE REVIEW AND HYPOTHESES

Process Flow of coal supply to the Power Plant

The supply of coal to power plant is a vital operational process managed by XYZ (Mulukhov et al. 2018). Belt conveyors can be adapted to various terrains and operational conditions, including steep inclines and declines. This process involves a complex but highly coordinated series of steps starting from coal extraction at the mine site, transportation via various material handling systems, and culminating in coal delivery to the power plant for combustion and electricity generation (Fedorko et al. 2018). Belt conveyors are highly efficient for transporting large quantities of coal over long distances in surface and underground mining operations. Each stage in this supply chain is critical to ensure efficiency, consistency, and fuel quality delivered to the power plant. At the power plant, coal is fed into the boiler system, which is combusted to produce steam. This steam turns turbines connected to generators, thus producing electricity. The success of this process relies on the consistent and uninterrupted supply of coal with predictable quality. The heat generated from combustion converts water in the boiler into high-pressure steam (Wibawa et al. 2020).

The CHF must, therefore, synchronize its operations with the daily and seasonal demands of the power plant. A delay in supply or a mismatch in coal quality can significantly impact the efficiency and emission profile of the power plant. The efficiency of coal-fired power plants can be optimized through various means, including improving the combustion process, optimizing boiler operation, and integrating CO2 capture technologies (Dzikuc et al. 2020). Moreover, high-moisture or low-calorific coal may increase fuel consumption and maintenance requirements. In coal-fired power plants, moisture in flue gas primarily originates from the combustion of hydrogen in coal and water used in wet flue gas desulfurization systems (Shuangchen et al. 2017). The coal supply process to the Power plant is as follows :

1. Mining Operation

   The process begins with coal mining from designated mining areas within PT XYZ's concession. The mining method is typically open-pit mining, which involves removing overburden to access coal seams near the surface. Large excavators and dump trucks extract and transport the raw coal (also called ROM—Run of Mine) from the mining fronts. Mining operations are carefully planned through short-term and long-term mine plans to ensure coal's sustainable and economical extraction. Involve removing the overlying soil and rock to access coal seams. This method is efficient but has significant environmental impacts, including landscape alteration, ecosystem loss, and soil destruction (Rouhani et al. 2023). Mining activities are supported by detailed geological mapping and quality control procedures to ensure that only coal with suitable specifications is extracted for the Power plant. The primary aim is to supply power plants with coal that meets specific quality constraints, such as calorific value, ash content, and sulfur content (Osipova, 2022). The coal is then temporarily stored in the ROM stockpile area near the pit before being transported to the next stage in the supply chain. After mining, the ROM coal is loaded onto dump trucks for transportation to the reclaim feeder area. The reclaim feeder is a transfer and regulation point in the coal handling. Conveyors are vital for the mining, processing, and transportation of coal in thermal power plants. They must operate efficiently to avoid major breakdowns and ensure the plant's continuous operation (Kumawat et al. 2019).

   In PT XYZ's operations, the reclaim feeder is strategically located to optimize the distance between the mining front and the conveyor system that supplies the power plant. In the mining process, two materials are excavated : the overburden (soil material on the top layer) and coal material. The overburden material excavated during mining operations will be transported along the conveyor system route to the designated dumping area. Meanwhile, the coal material will be directly transferred to the reclaim feeder for the subsequent supply process through the conveyor system. Mnzool et al (2024) argue that Reducing the total cycle time of trucks, which includes loading, hauling, dumping, and return times, can significantly enhance productivity. For instance, optimizing the haul road network and minimizing loading and dumping times are critical strategies. This stage is critical as it manages the coal flow rate and volume entering the conveyor system. The reclaim feeder ensures a steady and controlled coal discharge, preventing surges that may overload the conveyor or downstream crushing units. Operators monitor the coal's moisture content, grain size, and other physical characteristics to determine whether further treatment is necessary before conveyor transport.

2. Coal handling system

   Serifoglu et al (2002) ague that Belt conveyors are essential in mining, food processing, automotive, and packaging industries. The coal discharged from the reclaim feeder is transferred onto the conveyor system—a long, continuous belt conveyor spanning several kilometers. This conveyor acts as the primary mode of transport for coal from the reclaim area to the crushing facility and eventually to the power plant. PT XYZ has implemented electrified conveyor technology to reduce dependency on diesel fuel, improve environmental sustainability, and reduce operational costs. The conveyor system is designed for high capacity and can transport thousands of tons of coal daily. Implementation requires solving load distribution issues among multiple drives, which can be managed using modern frequency-controlled electric drives (Aliev, 2020). It has monitoring sensors and automatic belt cleaners to ensure efficient and uninterrupted operation. Safety systems are in place to stop the conveyor in case of overload, misalignment, or fire detection. The use of conveyor belts significantly reduces the cost per ton of coal transport and mitigates traffic and environmental issues associated with truck-based transportation. These systems use multiple sensors (e.g. gas detectors, temperature sensors) to monitor hazardous conditions in real-time. Data is transmitted wirelessly to a centralized server for continuous analysis, triggering alarms and notifications when safety thresholds are exceeded (Gopal et al. 2019).

Conveyor System Optimization

This study explores the theoretical foundations, key factors, and best practices in conveyor system optimization, drawing from international literature and real-world industrial applications. Conveyor optimization focuses on achieving higher throughput, lower energy consumption, and reduced operational wear and tear. Implementing real-time monitoring systems, such as those using Digital Twin technology, can optimize operational parameters and improve throughput by ensuring precise control and reducing spillage (Chen et al.2024). According to Zhao et al. (2010), key factors in conveyor optimization include the design of conveyor routes, selecting appropriate belt specifications, and synchronizing feeding and discharging points to minimize operational stoppages and system overloads.

Conveyor systems are central to efficient bulk material handling in mining, power generation, and manufacturing industries. Conveyor systems are known for their high levels of availability and reliability, making them more economical for transporting materials over both short and long distances, especially in mining operations (Ziegler 2023). A well-optimized conveyor system can significantly minimize operational costs, enhance material flow efficiency, and support achieving sustainability objectives. In the coal supply system to the power plant, the mining front is located approximately 2.2 kilometers from the power plant. The coal extracted from the mining front is transported by truck to the conveyor system. Here, the coal is transferred, and its grain size is reduced from an initial size of 600 mm to a final size of 50 mm using crushing equipment. The conveyor belt spans approximately 5 kilometers to transport the coal to the power plant. In addition to coal, overburden material (soil) is first excavated and transported to stockpile areas near the coal handling facility. However, this overburdened transport requires traveling around the existing conveyor route, creating inefficiencies.

One of the key optimization strategies is shortening the conveyor length to reduce the haul distance, the distance material must travel before entering the conveyor system or between conveyor transfer points. Reducing haul distance directly lowers energy consumption, increases throughput, and enhances the overall performance of the material handling system. Reducing the length of conveyors can lower the energy required for material transport. For instance, longer conveyors tend to have lower specific energy consumption per ton-meter compared to shorter ones, with reductions up to 36% (Jena 2023).

This study, supported by international literature and industrial case studies, explores the theoretical foundations and practical applications of conveyor length optimization for haul distance reduction. Haul distance refers to the distance that materials (such as coal, ore, or aggregates) must travel from the extraction or processing point to the conveyor system or between transfer stations within conveyor networks. According to Zhang and Xia (2014), long-haul distances result in higher truck usage, increased operational costs, longer cycle times, and greater environmental impacts.

Shorter haul distances reduce the wear and tear on trucks, leading to lower maintenance costs. Improved road conditions also contribute to reduced vehicle damage and maintenance needs (Bodziony et al. 2025). The benefits of shortening haul distances include:

- Reducing truck operating hours and maintenance costs,
- Lowering fuel consumption and emissions,
- Speeding up material loading times and system cycle times,
- Improving conveyor utilization and overall system stability.

Six Sigma

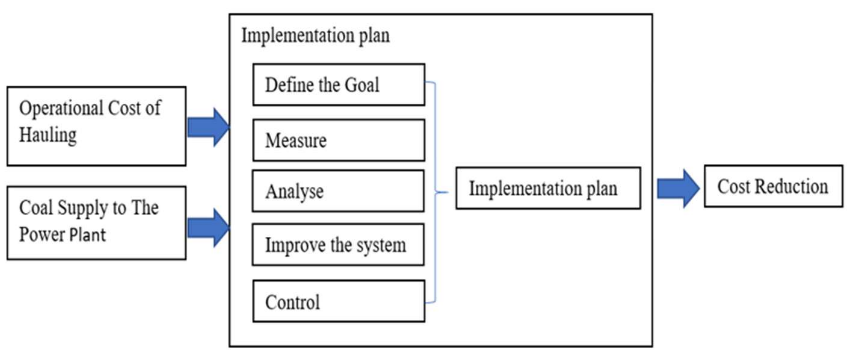
Six Sigma is an organized and systematic methodology for strategic process improvement and developing new products and services. It relies on statistical and scientific approaches to drastically reduce customer-defined defect rates. By systematically addressing inefficiencies and defects, Six Sigma helps organizations reduce costs and improve productivity. This is evident in various industries, including manufacturing and automotive sectors (Noori 2018). The core initiatives of Six Sigma are implemented through a problem-solving framework known as the Define-Measure-Analyze-Improve-Control (DMAIC) process. The DMAIC framework is a robust methodology for process improvement across various industries. By systematically defining, measuring, analyzing, improving, and controlling processes, organizations can achieve significant enhancements in quality, efficiency, and customer satisfaction (Kumar 2023). Six Sigma emphasizes the identification and prevention of variations. Six Sigma emphasizes the identification and prevention of variations through rigorous statistical analysis and structured methodologies. By focusing on reducing variations, Six Sigma aims to enhance the quality and efficiency of processes, leading to fewer defects and higher customer satisfaction (Hamid 2018). Furthermore, its principles focus on explicitly recognizing the root causes of defects and applying statistical process control to sustain continuous improvement (Abdelhamid, 2003). DMAIC is primarily used for existing processes. This approach utilizes various tools and techniques and incorporates financial analysis and project scheduling development concepts. Project scheduling, an essential aspect of DMAIC, involves planning and sequencing activities to meet project deadlines and optimize resource allocation (Dayoub N., & Fakhratov, M 2021). The DMAIC methodology is particularly effective when applied to existing operations where achieving a defined level of performance results in the expected benefits (Chakraborty & Tan, 2012).

DMAIC is a process improvement methodology derived from the Six Sigma framework, which aims to enhance quality and efficiency by identifying and eliminating the root causes of defects or problems within business processes. Six Sigma tools and techniques significantly improve efficiency by optimizing processes and reducing waste. This leads to better quality, productivity, and customer satisfaction (Makwan & Patange, 2021). DMAIC stands for five key phases in the improvement process: Define, Measure, Analyze, Improve, and Control. Six Sigma is a data-driven methodology aimed at improving process quality by reducing variability and defects. It employs the DMAIC cycle, which stands for Define, Measure, Analyze, Improve, and Control, to systematically enhance processes and achieve near-perfect quality levels (Harolds, 2021).

a. Define Phase: This initial phase focuses on clearly identifying the business problem, project objectives, customer requirements, and the scope of the process to be improved.
b. Measure Phase: This phase aims to collect relevant data to understand the current state of the process and establish baseline metrics for comparison.
c. Analyse Phase: In this critical phase, data is analyzed to determine the root causes of problems. Various analytical tools, including Root Cause Analysis (RCA) and the Fishbone Diagram, are used.
d. Improve Phase: Once root causes are validated, the team designs and tests improvements to solve the identified problems.
e. Control Phase: The final phase focuses on sustaining improvements and preventing the recurrence of problems

Conceptual Framework

A conceptual framework is a cognitive instrument used to systematize concepts and construct a framework for the cognitive processing of an issue or subject. A conceptual framework is a system of interconnected concepts that provides a thorough understanding of an event. A conceptual framework is a system of concepts connected with a specific thematic or problem domain, forming a structured semantic space. It serves as a mental imaging and graphic thinking tool that helps convert raw thoughts into structured communication (Khamu et al. 2019). Efficient coal handling is critical for minimizing operational costs, maximizing throughput, and supporting sustainability goals in mining and power generation operations. One of the significant factors affecting coal handling efficiency is the haul distance, the distance coal must travel from the mining face or stockpile to the conveyor system or plant. Figure 4 shows a conceptual framework for optimizing the CHF route for coal supply to the power plant.



Source : Constructed for this study, 2025

Figure 4
Conceptual Framework

The conceptual framework includes three main components, Input, Process, and Output, to address the research questions related to shortening the hauling distance and optimizing the coal conveyor system for efficient coal supply to the power plant.

a) The Input stage collects essential data and insights that inform the research process:

- Operational System: Current coal handling and transportation infrastructure.
- Operational Data: Data on daily operational parameters like coal volume, handling time, and conveyor performance.
- Hauling Distance: Existing routes and distances covered by trucks or conveyors.
- Transportation Costs: Associated hauling costs, including labor, fuel, and maintenance.

b) The Process phase focuses on applying methods and techniques to DMAIC Six Sigma.
In industrial operations, continuous improvement is essential to achieve efficiency, cost savings, quality assurance, and sustainability. Six Sigma offers a structured, data-driven methodology to systematically improve processes, eliminate inefficiencies, and sustain performance gains. Within Six Sigma, the DMAIC framework — Define, Measure, Analyze, Improve, Control serves as the core roadmap for problem-solving and optimization initiatives. This conceptual framework applies DMAIC to optimize operational processes by shortening haul distances, redesigning system layouts (such as conveyor routes), or improving system throughput.

c) The Output stage delivers actionable outcomes to improve operations:
- Design Project: Implementation-ready plans for optimized conveyor pathways.
- Efficiency: Improved operational metrics such as reduced hauling distance, lower costs, and increased coal supply reliability

METHOD

The data analysis method in this study is designed to systematically evaluate operational data collected from the mining operations and coal handling facilities supplying coal to power plant. The primary objective of the analysis is to identify inefficiencies, measure operational performance, and propose strategic improvements to optimize coal supply.
The analysis will be conducted using a combination of quantitative and qualitative techniques, including:

1. Define Phase: Problem Identification.
In the Define phase, the author begins with a thorough review and observation of mining operations, the transportation of coal from the mining front through the coal handling facility (CHF) route, and the overburden dumping area. This stage is crucial as it helps identify the key problems and inefficiencies within the current system.
2. Measure Phase: Data Collection and Baseline Measurement.
The Measure phase collects historical and real-time data, such as coal and overburden haul distances, transported volumes, and transportation costs. The purpose of this phase is to gather relevant data to understand the process's current state and establish baseline metrics for comparison.
3. Analyze Phase: Identify Root Cause.
In this critical phase, the collected data is analyzed to determine the root causes of inefficiencies. Several analytical tools are utilized, particularly Root Cause Analysis (RCA). The Fishbone Diagram (Ishikawa Diagram) method is used to trace underlying issues, focusing on excessive haul distances, poor layout configurations, and disruptions in material flow. This phase includes analyzing

process flow and performance data and Identifying bottlenecks and sources of variation.

4. Improve Phase: Strategy Development.
   The improvement phase involves developing targeted strategies based on the findings of the analysis. Possible optimization strategies—such as rerouting the conveyor or repositioning the reclaim feeder—will be tested through basic simulation models to evaluate their impact on operational efficiency. A Cost-Benefit Analysis will also be conducted to assess the financial feasibility of the proposed improvements to the conveyor system and material handling process.
5. Control Phase
   The final phase emphasizes sustaining improvements and preventing the recurrence of problems. A detailed implementation roadmap will be developed, outlining step-by-step actions, execution timelines, and project completion targets to ensure the project stays on track. This phase also includes a risk assessment, identifying potential challenges that may arise during implementation and providing mitigation plans to address them proactively.

The analysis results will serve as the basis for strategic recommendations to improve the reliability, cost-efficiency, and sustainability of the coal supply chain to the power plant.

RESULTS AND DISCUSSION

The CHF conveyor line is the primary route for coal delivery from the mining front to the power plant. The system involves transporting coal from the mine using dump trucks to a reclaim feeder. From there, the coal is transferred to a conveyor system approximately 5 kilometers long, passed through a crusher, and delivered to the power plant. The MTBU mine is the power plant's designated coal supplier.

Define Phase

In the Define phase, the research begins with a comprehensive review and direct observation of mining activities, the transportation of coal from the MTBU front to the Coal Handling Facility (CHF), and the overburden dumping area. This phase is essential for identifying the current problems, including the increasingly long coal haul distance (5 kilometers) to the CHF feeding conveyor and limited optimization of the overburden dumping area due to conveyor bottlenecks.

Measure Phase : Data Collection and Baseline Measurement

During the Measure phase, quantitative and qualitative data were collected from field operations, including hauling distances for coal and overburden, volumes transported, and associated costs. In addition, the layout of the coal supply from the mining front to the CHF line was also. The CHF line is the route used to deliver coal to the power plant, totaling 5,090 meters. This CHF line consists of:

1) A reclaim feeder with a capacity of 500 tons per hour.
2) A Crusher, in which coal with a maximum input size of 600 mm is crushed to 150 mm in the first stage and further crushed from 150 mm to 50 mm in the second stage. The crusher has a capacity of 500 tons per hour.
3) Conveyor belts, which consist of three segments:
   - CC 10, with a length of 420 meters,
   - OLC 11, with a length of 3,870 meters,

- OLC 12, with a length of 394 meters

The arrangement and conveyor system layout of the CHF line for coal supply to the power plant can be seen in the image below. Coal transported from the mining front is collected at the CC10 stockpile. From there, the coal is delivered to the power plant through the reclaim feeder and the conveyor lines CC10, OLC 11, the crusher, and OLC 12. The target coal supply delivered to the power plant is sized at –50 mm, which is required for the power plant's fuel needs. As for the year 2024, the coal supply to the power plant is 520,674 Tons In the mining system, to extract coal, overburden material (soil) must also be excavated and managed adequately for dumping. At the MTBU mine, the excavated overburden is transported and dumped in a designated area near the CHF line.

However, the dumping area cannot directly cross the CHF route, so currently, the overburden is hauled along the CHF route with a dumping distance of approximately 4 kilometers. The overburden from the MTBU mine is dumped in the designated dumping area, with a total volume of 5.880.000 BCM recorded in the year 2024.

Analyse Phase : Identify Root Cause

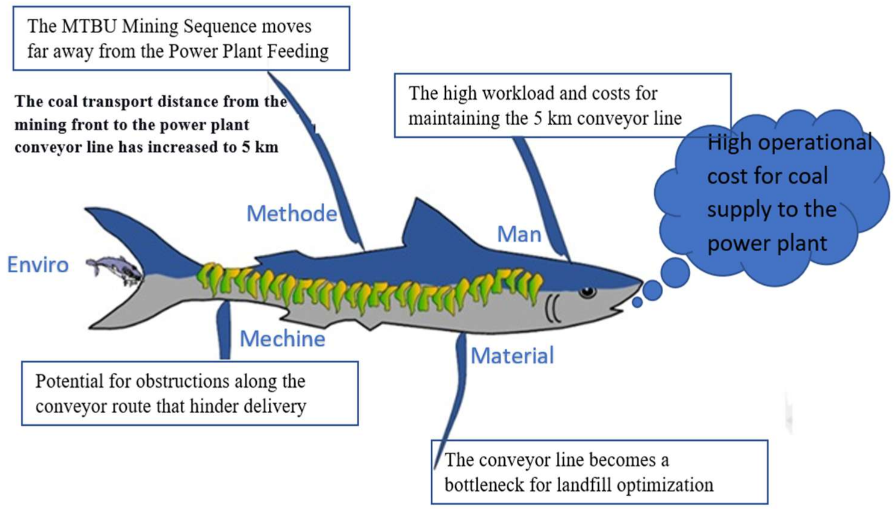
In the coal supply process to the power plant through the conveyor system, the coal is first transported from the mining front to the CHF (Coal Handling Facility) line before being delivered to the power plant via the conveyor. The hauling distance of coal from the mining front to the CHF line is 5 kilometers. Therefore, the transportation cost of the coal can be calculated based on this distance, and the cost of coal delivery to the power plant is 520.674 tons per year. Moreover, the cost of coal hauling to the CHF system is 14.953.275.657 Rupiah per ton. The excavated overburden will be dumped at the designated dumping area, with a hauling distance of 4.07 kilometers from the mining front to the dumping site. Accordingly, the transportation cost for the overburden can be calculated based on this distance. Overburden delivery to the dumping area costs 5.880.000 cm per year. Moreover, the cost of overburden hauling to the dumping area is 165.828.412.680 rupiah per ton.

In the Analyze phase, the primary goal is to identify the root causes of inefficiencies and cost drivers within the current coal transport route from the MTBU mining front to the CHF (Coal Handling Facility) , which currently spans 5 kilometers. Through this analysis, the study aims to understand why the existing system results in high transportation costs, limited dump site access, and operational bottlenecks. Based on the data collected during the Measure phase, it was found that:

- Coal is transported 5 km from the mining front to the reclaim feeder via dump trucks.
- The same line is used as an access route for transporting overburden (topsoil and waste material) to the dumping area near the CHF line, increasing congestion.
- Conveyor utilization is suboptimal due to its current fixed location, resulting in inefficient routing as the mining front shifts.

Using a Fishbone Diagram (Root Cause Analysis), the study identifies the primary root cause: the extended coal hauling distance of 5 km from the mining front to the conveyor, significantly increasing operational costs. The analysis highlights bottlenecks caused by layout inefficiencies and topographical challenges. Base on the situation appraisal of the CHF line operations, the top priority issue to be addressed is the suboptimal production and operations at MTBU. The mining front has moved closer to the power plant, increasing transportation costs to the conveyor system.

To determine the root cause of this problem, a detailed Fishbone analysis is conducted as follows:



Source : Fishbone Analyzed by authors, 2025

Figure 3
Fishbone Diagram for Root Cause Analysis

Based on the fishbone diagram provided, which applies the Root Cause Analysis (RCA) method, the following are the key problem areas, root causes, and the identification of the main root cause affecting the inefficiency of coal transport operations from the MTBU mine to the power plant via Conveyor Line. After analyzing all contributing factors, the main root cause selected is: "The coal transport distance from the mining front to the power plant conveyor line has increased to 5 km, causing higher operational costs, greater energy consumption, and inefficiencies in overburden dumping and coal delivery."

This dominant factor directly influences cost, time, risk exposure, and environmental impact. Therefore, optimizing or rerouting the conveyor system closer to the mining front is the most strategic solution. It is necessary to re-engineer the conveyor system to bring it closer to the mining front. Based on the current layout, it is possible to install or construct a new conveyor line extending closer to the mining front and the power plant.

Improve Phase : Business Solution

A brainstorming session was conducted to implement improvement engineering on the root cause—namely, the increasing coal hauling distance from the mining front to the power plant feeding conveyor, which currently reaches 5 kilometers. The objective is to reduce the hauling distance by relocating or redesigning the material flow system, particularly the crusher and conveyor line, so that it is closer to the mining front, resulting in Reduced transportation costs, Improved energy efficiency, Enhanced system reliability, and Smoother integration between mining and power generation systems.

From the brainstorming, two alternative solutions were identified for installing or constructing a conveyor line closer to the mining front, namely:

1. Construction of crusher lines by moving existing lines
   This alternative involves relocating the existing crushing system (crusher, reclaim feeder, transfer tower, mechanical and electrical components) from its current location near the old mining front to a new location closer to the active mining front and power plant.
2. Construction of crusher lines by purchasing new crushers
   This alternative proposes installing an entirely new crushing system from scratch, including all required mechanical, structural, and electrical components, near the new mining front.

Table 1 shows the specification data for the two alternatives so that it can show a comparison of the two alternatives.

Table 1
The Specifications Data for the Two Alternatives

Criteria	Relocating the Existing Crusher Line	Constructing a New Crusher Line
Cost	Rp. 9,100,000,000	Rp. 21.000.000.000
Size input (mm)	400 mm	400 mm
Size Out Put (mm)	-50 mm	-50 mm
Capacity (tons/hr)	500 Ton/Hour	500 Ton/Hour
Manufacture	1 month	8 months
Operation hours (hour)	24 Hours	24 hours
Purchase of equipment	Using existing	Purchase new
Equipment construction	10 months	15 months
Optimization of existing equipment	90 %	50 %

Source : Data Analyzed, 2025

In determining alternative solutions, several criteria must be met, namely:

a. Required criteria:
   1. Cost
   2. Crusher input size 400 mm
   3. Crusher output size under 50 mm
   4. Capacity 500 tons/hours
b. Desired criteria:
   1. Project execution duration is expected to be completed quickly
   2. Financial is expected to low cost
   3. Technical implementation is easy for construction and operation
   4. Sustainability for Alignment with long-term goals
   5. Environmental

The following table 2 shows the assessment of these criteria:

Table 2
Data for Required Criteria for New a Line

"Must Criteria"	Relocating The Existing Crusher Line	Constructing A New Crusher Line
Cost	Rp. 13.000.000.000	Rp. 30.000.000.000
Size Input (400 Mm)	Yes	Yes
Size Out Put (-50 Mm)	Yes	Yes
Capacity (500 Tons/Hour)	Yes	Yes

Source : Data Analyzed, 2025

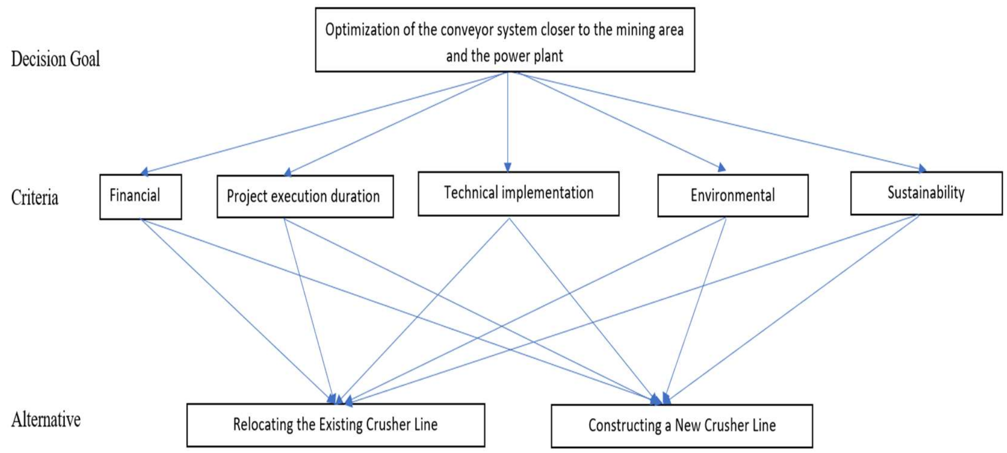
The following table 3 shows the Data for Desired Criteria for New Line.

Table 3
Data for Desired Criteria for New Line

Criteria	Weight	Relocating the Existing Crusher Line		Constructing a New Crusher Line	
		Score	Weight x Score	Score	Weight x Score
Project Execution Duration	9	9	81	7	63
Financial	8	9	72	7	56
Technical Implementation	8	7	56	8	64
Sustainability	8	9	72	8	64
Environmental	8	9	72	8	72
Total Weigh x score			355		311

Source : Data Analyzed, 2025

In addition to using the scoring method based on required and desired criteria, the author also applied the Analytic Hierarchy Process (AHP). AHP is used as a quantitative method to determine the relative weight of importance for various criteria influencing the selection of the optimization CHF line for coal supply to the power plant. This method incorporates input from relevant stakeholders and considers multiple key aspects, including Financial, Project execution duration, Technical implementation, Environmental, and Sustainability. The AHP analysis was conducted using a questionnaire completed by seven expert stakeholders with domain knowledge in the relevant areas. Figure 4 shows the AHP structure for optimization of the conveyor system closer to the mining area and the power plant.



Source : Data Analyzed, 2025

Figure 4
Structure AHP

Table 5 shows the Calculation of Priorities and Eigenvalue for the Criteria Comparison Matrix and Criteria Weight Matrix.

Table 5
Calculation of Priorities and Eigenvalue

Criteria Comparison Matrix

Criteria	C1	C2	C3	C4	C5
C1	1.00	1.42	1.66	0.78	0.81
C2	0.70	1.00	1.37	0.58	0.35
C3	0.60	0.73	1.00	0.49	0.31
C4	1.27	1.72	2.04	1.00	0.62
C5	1.23	2.76	3.23	1.60	1.00
Total	4.81	7.63	9.30	4.46	3.09

Criteria Weight Matrix

Criteria	C1	C2	C3	C4	C5	Vector Eigen
C1	0.21	0.19	0.18	0.18	0.26	0.20
C2	0.15	0.13	0.15	0.13	0.11	0.13
C3	0.13	0.10	0.11	0.11	0.10	0.11
C4	0.26	0.23	0.22	0.22	0.20	0.23
C5	0.26	0.36	0.35	0.36	0.32	0.33

Source : Data Analyzed, 2025

The questionnaire data produced the following pairwise comparison matrix *:*

Λ max	5.0220
RI	0.0188
CR	0.0049

With a Consistency Ratio (CR) of less than 0.1, the comparison matrix is considered consistent and valid for use in AHP analysis.
In optimizing the CHF route for coal supply to the power plant, there are 2 alternatives that can be a solution, namely

- Relocating the Existing Crusher Line (Alternative 1)
- Constructing a New Crusher Line (Alternative 2)

To find the best alternative in selecting a solution, the criteria used are financial, Project Execution Duration, Technical Implementation, Environmental, and Sustainability. Table 6 shows a comparison of the solution selection for the two alternatives for the Calculation of Priorities and Eigenvalue

Table 6
Calculation of Priorities and Eigenvalue

Financial	Alternative Comparison Matrix			
	Alternative	Alternative 1		Alternative 2
	Alternative 1	1.00		372.71
	Alternative 2	0.00		1.00
	Total	1.00		373.71
	Alternative Comparison Matrix			
	Alternative	Alternative 1	Alternative 2	Vector Eigen
	Alternative 1	1.00	1.00	1.00
	Alternative 2	0.00	0.00	0.00
Project Execution Duration	Alternative Comparison Matrix			
	Alternative	Alternative 1		Alternative 2
	Alternative 1	1.00		315.00
	Alternative 2	0.00		1.00
	Total	1.00		316.00
	Alternative Comparison Matrix			
	Alternative	Alternative 1	Alternative 2	Vector Eigen
	Alternative 1	1.00	1.00	1.00
	Alternative 2	0.00	0.00	0.00
Technical of Implementation	Alternative Comparison Matrix			
	Alternative	Alternative 1		Alternative 2
	Alternative 1	1.00		45.00
	Alternative 2	0.02		1.00
	Total	1.02		46.00
	Alternative Comparison Matrix			
	Alternative	Alternative 1	Alternative 2	Vector Eigen
	Alternative 1	0.98	0.98	0.98
	Alternative 2	0.02	0.02	0.02
Environmental	Alternative Comparison Matrix			
	Alternative	Alternative 1		Alternative 2

	Alternative 1	1.00		215.19
	Alternative 2	0.00		1.00
	Total	1.00		216.19
	Alternative Comparison Matrix			
	Alternative	Alternative 1	Alternative 2	Vector Eigen
	Alternative 1	1.00	1.00	1.00
	Alternative 2	0.00	0.00	0.00
Sustainability	Alternative Comparison Matrix			
	Alternative	Alternative 1		Alternative 2
	Alternative 1	1.00		315.00
	Alternative 2	0.00		1.00
	Total	1.00		316.00
	Alternative Comparison Matrix			
	Alternative	Alternative 1	Alternative 2	Vector Eigen
	Alternative 1	1.00	1.00	1.00
	Alternative 2	0.00	0.00	0.00

Source : Data Analyzed, 2025

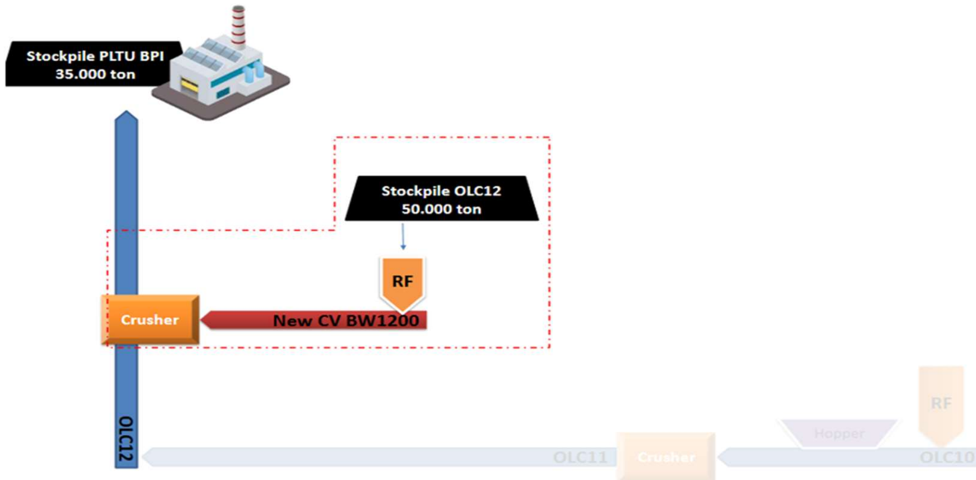
Figure 7 shows the Decision Matrix for Alternative Selection for two alternative solutions for Relocating the Existing Crusher Line (Alternative 1) and Constructing a New Crusher Line (Alternative 2). Based on the results of the AHP analysis, the selected alternative is the relocation of the existing crusher line**.** Accordingly, this alternative will be the recommended solution for optimizing the CHF line for coal supply to the power plant. As shown in the map, the hauling distance for the new design is 2.2 kilometers.

Table 7
Decision Matrix for Alternative Selection

Criteria	Alternative 1	Alternative 2	Criterion Weight
C1	1.00	0.00	0.20
C2	1.00	0.00	0.13
C3	0.98	0.02	0.11
C4	1.00	0.00	0.23
C5	1.00	0.00	0.33
Global Score Alternative 1			0.99
Global Score Alternative 2			0.01

Source : Data Analyzed, 2025

The plan to shorten the CHF line involves reducing the number of conveyor sections from the original three sections OLC 12, OLC 11, and CC 10 to only two sections, namely OLC 12 and New CC10. This includes relocating the existing Crusher and Reclaim Feeder (RF) to the New CC10 location. The coal from the mining front will be transported to the new route with a distance of 2.2 kilometers. It will then be conveyed along a belt line with a length of 534 meters. Figure 4 shows the optimized form of the CHF route which has been shortened to approach the coal power plant.



Source : Data Analyzed, 2025

Figure 4
Design for the Shortening of the CHF Line for Coal Supply to the Power Plant

By optimizing the CHF conveyor route, specifically shortening the original 5 km line (consisting of 3 sections) to only 0.5 km several benefits can be achieved :

1. Efficiency in coal hauling costs : The coal transport distance from the mining front to the CHF feeding system is reduced from 5 km to 2.2 km, resulting in an annual cost savings of approximately IDR 3,775,774,769.84
2. Efficiency in overburden hauling costs : The overburden transport distance from the MTBU mining front to the dumping area is reduced from 4 km to 2.8 km, with annual savings of approximately IDR 35,337,465,240.00
3. Efficiency in electricity consumption : An operational energy usage reduction of approximately 164,797.50 kWh per year.
4. Efficiency in diesel fuel consumption : A reduction of approximately 148,741.67 liters per year for mining operations.
5. Efficiency in maintenance costs : Estimated annual savings of IDR 770,000,000
6. Total Carbon Emission Reduction / Year 520.22 tons of CO_2

Implementation Plan

A structured implementation plan outlines the project's timeline, responsibilities, and performance monitoring. The key risk factors include potential delays in construction, land acquisition issues, and equipment availability challenges. Planned Activities and Execution Timeline: The implementation of this project is scheduled to take place over 10 months. The initial phase focuses on planning and preparation, including identifying requirements, defining project objectives, and developing a detailed work plan. Following the planning phase, the execution stage begins, during which project tasks are carried out according to the established plan. This process is conducted with precision and efficiency, ensuring optimal utilization of resources. Regular progress monitoring tracks milestones and ensures the project stays on schedule.

The Control phase ensures that the improvements achieved during the improvement phase are successfully sustained over the long term. This involves the development of a clear and detailed implementation plan and proactive risk mitigation strategies to prevent the recurrence of inefficiencies and monitor progress toward optimized performance. To realize the project or solution for optimizing the coal handling facility route, Table 8 shows the time frame for its implementation.

Table 8
Implementation Plan of Conveyor Line Shortening Of CHF Line for Coal Supply to the Power Plant

No	Work Description	Month									
		1	2	3	4	5	6	7	8	9	10
A. WORK PREPARATION											
1	Land Preparation and Construction of New Stockpile										
2	Civil Foundation										
3	Planning and Engineering										
4	Fabrication for Construction										
5	Transportation of Construction Materials to Site										
6	Erection of New Conveyor Line										
7	Installation of Mechanical Components										
8	Installation of Electrical and Control Components		-								
10	Installation of Electrical Power Supply										
B. CUT-OFF WORK											
1	Relocation of Reclaim Feeder OLC10 to the New Line										
2	Relocation of Drive Unit, Magnetic Separator, and Belt Scale from OLC10 to OLC11A										
3	Relocation of Crusher Unit OLC10 to the New Line										
C. COMMISSIONING TEST WORKS											
1	Functional Testing										
2	Commissioning Test										

Source : Data Analyzed, 2025

Control

A comprehensive monitoring strategy must be implemented to ensure that the construction of the new route for optimizing the CHF Power plant conveyor system is executed effectively. The monitoring process focuses on progress control, compliance with design specifications, safety assurance, and risk mitigation.

1) Progress Monitoring
   Progress is tracked through weekly and monthly work plans and milestone tracking. Each project phase land preparation, foundation works, structural installation, mechanical and electrical installation, and commissioning—is evaluated against predefined timelines.

2) Quality Control
All materials and installation work must meet the quality standards and specifications outlined in the engineering design documents. At each stage, regular inspections and quality assurance (QA) audits are conducted.
3) Health, Safety, and Environment (HSE) Compliance
Strict monitoring of HSE protocols is enforced throughout the construction.
4) Cost Monitoring
Actual expenditures are regularly compared with the budget plan to prevent cost overruns.
5) Risk Management Monitoring
Potential risks such as equipment delays, land access problems, or weather disturbances are tracked continuously, and mitigation plans are updated accordingly.

CONCLUSION AND SUGGESTION

This study successfully answers the research questions by identifying core inefficiencies in the CHF line and proposing a technically and economically sound optimization strategy. By optimizing the CHF conveyor line specifically shortening the original 5 km line (consisting of 3 sections) to only 0.5 km—several benefits can be achieved :

1. Efficiency in coal hauling costs : The coal transport distance from the mining front to the CHF feeding system is reduced from 5 km to 2.2 km, resulting in an annual cost savings of approximately IDR 3,775,774,769.84
2. Efficiency in overburden hauling costs : The overburden transport distance from the MTBU mining front to the dumping area is reduced from 4 km to 2.8 km, with annual savings of approximately IDR 35,337,465,240.00
3. Efficiency in electricity consumption : An operational energy usage reduction of approximately 164,797.50 kWh per year.
4. Efficiency in diesel fuel consumption : A reduction of approximately 148,741.67 liters per year for mining operations.
5. Efficiency in maintenance costs : Estimated annual savings of IDR 770,000,000
6. Total Carbon Emission Reduction / Year 520.22 tons of CO_2

Based on the findings and proposed solution, the following suggestions :

1. For Operational Efficiency :
   - Implement real-time monitoring tools to track hauling efficiency, conveyor performance, and energy consumption post-optimization.
   - Introduce preventive maintenance programs and capacity simulations to avoid future bottlenecks.
2. For Environmental and Cost Benefits :
   - Leverage the carbon reduction results (estimated 10 tons CO_2 per year) as part of ESG (Environmental, Social, Governance) reporting.
   - Optimize land use planning for future overburden dumping areas to avoid overlap with critical coal supply infrastructure.
3. For Future Research :
   - Extend the study by applying simulation modelling (e.g., Arena or Any Logic) to forecast multi-year impacts of conveyor system upgrades.
   - Explore using the Internet of Things (IoT) for predictive analytics and conveyor fault detection systems.

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