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Enhancing Fuel Ratio Efficiency for Sustainable Operations in Pit KX Mining: DMAIC Methodology

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ABSTRACT: PT ABC is one of Indonesia's largest coal mining businesses, and the mining. Pit KX is one of the company's pits worked by contractors, and it has been mined since 2008. According to the company's historical data from January 2022 to June 2023, overburden and coal production from Pit KX has decreased while fuel consumption has grown. Fuel is a major cost component in mining operations. The overall fuel cost represents around 35% of the company's total operational cost. This study investigates the use of the DMAIC (Define, Measure, Analyze, Improve, Control) approach as a systematic framework for improving fuel ratio efficiency and promoting sustainable practices in pit KX mining operations. The DMAIC technique provides a disciplined pathway for discovering, assessing, and eliminating fuel-related inefficiencies. DMAIC offers a disciplined framework for improvement. By implementing DMAIC methodology, it can systematically identify and address inefficiencies in fuel utilization leading to reduced operational costs, minimized environmental impact, and enhanced sustainability of pit KX mining operations.

KEYWORDS: DMAIC, Fuel Ratio Efficiency, Mining Sustainability, Pit KX Mining Operations

INTRODUCTION

What is the issue?

The mining world is strongly influenced by the coal price in the market. When the price of coal is at a high level, the company's profits will be greater and vice versa. The increase in coal prices is in line with the increase in fuel prices which are also high but this does not apply preferably because if coal prices fall, it does not make fuel prices also fall because there are many factors that affect fuel price. That is why fuel prices are one of the factors that concern all companies and fluctuations in fuel prices will greatly affect company costs and of course operational costs. For PT. ABC itself, the purchasing cost of fuel takes a very large portion of around 35% of PT. ABC's total operating costs from 2022. The market price of fuel is impossible for mining companies to control. Until June 2023, the actual fuel price was higher than the planned fuel price in 2023. Although coal prices during Semester 1 of 2023 were high, with the deviation or gap in fuel costs, PT. ABC will bear the burden of excess fuel costs to cover the difference in costs so as not to disrupt operations or may result in operational termination because it is no longer efficient. This is certainly not acceptable to PT. ABC's management and shareholders if operations are stopped because it will have an impact on the company's image, company income and PT. ABC's operations are no longer considered efficient, which has an impact on PT. ABC investors and shareholders will consider investing in PT. ABC.

Why is the issue required to be researched?

PT. ABC management is very serious in reducing the fuel ratio in its operations, one of which is the fuel ratio in contractor operations. It can be seen from the data in the figure above that fuel ratio in Pit KX has exceeded the quota and of course the excess use of fuel from the quota given will have an impact on the operational costs of the contractor itself and PT. ABC's operational costs because in giving the quota, PT. ABC also bears costs such as purchasing cost, transportation and handling costs that may impact to production loss from other contractors because they have to meet the shortages needed by other parties due to wasteful contractors. Therefore, this research is focused on how to reduce fuel ratio in contractors by optimizing fuel consumption.

Research Questions

The following questions need to be answered:

- What are the factors that affect high fuel ratio in the mining contractor?
- What is the best scenario to reduce fuel ratio?

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Research Objectives

This study is purposed to analysis contributing factors that effect to higher fuel ratio in the mining contractor in current situation and found the best scenarios to reduce fuel ratio and can be used by PT. ABC's management to make decision.

Research Scope

This research scope will focus only analysis main factors that contributed most to the high fuel ratio. The study will use historical data of fuel ratio from January 2022 – June 2023.

Limitation

This study will only focus in Pit KX within contractor responsibility area under Mining Contract Department PT. ABC and may not be applicable to other Pit in PT. ABC and contractors.

RESEARCH METHODS

To overcome problems discovered, the authors employ the Six Sigma methodology, which includes the stages of Define, Measure, Analyze, Improve, and Control (DMAIC).An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it. Wherever Times is specified, Times Roman or Times New Roman may be used.

The first approach is to detect the problem by examining underperformance of fuel ratio compare to specified targets. This assessment comprises determining the baseline conditions of the present system in order to compare it to the enhanced system. After identifying the primary issue, the author used fishbone analysis to find its root cause. Alternative solutions are given and shared for potential application in the field after through discussions and collaboration. The author then analyzes data and conducts field observations to find additional difficulties and opportunities for improvement in the overburden-stripping process.

Figure 1. Research Methodology Framework

RESULT AND DISCUSSION

1. Define Phase

This phase involves clearly understanding and defining the problem or opportunity, as well as establishing project goals and objectives. The steps are described below:

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Project Charter	
Data	
Project Title	Fuel Efficiency at Pit KX
Project Sponsor	PT. ABC Mining Manager
Project Manager	PT. ABC Superintendent Operation
Project Starts	July 01th, 2023
Project End	December 31th, 2023
Project Team Member	4 Mining Engineer Operation Section PT. ABC 2 Mining Engineer Contract Admin Section PT. ABC 2 Production Engineer Contractor PT. ABC 2 Section head Production Contractor PT. ABC 1 Departement Head Engineering Contractor PT. ABC
Project Budget	USD 105 Millions
Opportunity / Problem Statement	
What is happening?	PT. ABC actual fuel ratio is above the fuel ratio budget.
When did the problem start?	Since January 2022
Where is the problem occuring?	Hauling OB, Loading OB, and Hauling Coal Mine
Who is experiencing the pain?	PT. ABC & Contractor Management
Business Impact	
What is the quantified value creation of the project	Reduce fuel ratio from Hauling OB, Loading OB, and Hauling Coal Mine so that the use of fuel from these 3 (Three) activities can increase overburden and coal production
Key Metrics	
What is the improvemement objective and target	• Reduce losses by the end of December 2023 • Improve operational efficiency and productivity • Enhance cost savings through reduced fuel expenditure.
Project Scope	
Area	PT. ABC Mining Area - Pit KX
Task Sequence	Hauling OB, Loading OB, and Hauling Coal Mine Activity
Discussion boundary	Focus on proposed solution to improve fuel ratio performance
Implementation Project Plan	
Define	January 01st, 2022 - June 30th, 2023
Measure	July 2023 - December 2023
Analysis	August 2023 - December 2023
Improve	July 2023
Control	July 2023

Figure 2. Project Charter
(**Source:** by Author)

2. Measure Phase

The authors conduct research on what factors contribute to the high fuel ratio. The material excavated from Pit KX consists of topsoil, overburden, and coal with a total planned material of 90.5 million bcm (bank cubic meter), but the actual achievement of total material is only 69.0 million bcm. Meanwhile, actual fuel ratio of 1.33 Liters/bcm is higher than the budget of 0.96 Liters/bcm or 38.15 % higher than budget. In the percentage column below, the fuel ratio percentage is the difference between actual fuel ratio minus plan fuel ratio and compared to the plan fuel ratio.

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ACTIVITY	Total Material Budget	Fuel Consumption Budget	Fuel Ratio Budget	Total Material Actual	Fuel Consumption Actual	Fuel Ratio Actual	Percentage
	BCM	Liter	L/BCM	BCM	Liter	L/BCM	
LOADING-OB	78,399,511	17,639,890	0.23	55,867,673	14,009,215	0.25	11.45%
HAULING-OB	78,399,511	74,072,122	0.94	55,867,673	62,791,654	1.12	18.96%
LOADING-COAL_MINE	8,812,433	4,270,641	0.48	4,993,124	2,383,953	0.48	-1.48%
HAULING-COAL_MINE	8,812,433	11,275,190	1.28	4,993,124	6,692,759	1.34	4.76%
LOADING-COAL_RECLAIM	3,084,352	1,494,724	0.48	1,162,270	34,783	0.03	-93.82%
HAULING-COAL_RECLAIM	3,084,352	2,412,912	0.78	1,162,270	243,643	0.21	-73.20%
LOADING-TS	3,349,484	1,507,268	0.45	4,524,132	1,612,735	0.36	-20.78%
HAULING-TS	3,349,484	4,003,767	1.20	4,524,132	3,561,811	0.79	-34.14%
SUPPORT				1,307,699	147,476	0.11	100.00%
OTHER				1,217,216	42,524	0.03	100.00%
TOTAL	90,561,428	86,854,580	0.96	69,072,114	91,520,554	1.33	38.15%

Figure 3. Fuel Ratio by Activity
(**Source:** Company internal data)

There are 3 (Three) major activities carried out by the contractor that contribute to higher fuel ratio factors such as:

- Hauling Overburden, increased by 18.9%,
- Loading Overburden increased by 11.4%,
- Hauling Coal Mine increased by 4.7%.

For 2 (two) Support activity and other activity there are no volume and quantity budget because it has been included in the calculation of all materials both overburden, coal mine, coal reclaim, and topsoil. However, the actual contractor has identified the volume of material included in the support and other activities. Support activities calculated by the contractor include the volume of overburden carried out by graders, dozers, drilling, etc. And for other activities include the volume of water and mud from pumping activities, pond maintenance activities, water treatment activities, clearing, etc. which are converted into volume including the quantity of fuel used.

3. Analyze Phase

3.1. Fuel Consumption

From the weekly and monthly fuel consumption data from January 2022 to June 2023, total fuel consumption from contractor activities in Pit KX is 91.5 million liters. There are 3 (three) major activities with the highest fuel consumption such Hauling Overburden of 62.8 million liters or 68.6%, Loading Overburden of 14.0 million liters or 15.3%, and Hauling Coal Mine of 6.6 million liters or 7.3%.

3.2. Hauling Overburden

The dump truck used to transport the overburden is Komatsu HD-785. From the company data on figure 3, actual fuel ratio is 1.12 Liter/bcm or 18.9 % higher than plan 0.94 Liter/bcm. Based on the investigation conducted, the authors identified factors that create a high fuel ratio from overburden hauling activities from Pit KX including:

a. Longer Distance from loading point to dumping point
   This overburden material is moved to a certain location based on the company's medium and long-term plans. The actual average dumping distance of overburden from the graph above is 5.25 km which is much higher than the planned average distance of 4.58 km. The longer dumping distance is due to the formation of the dumping area starting from the lowest bench and pit excavation is getting deeper in accordance with the long-term plan set by the company.
b. Haul Road Condition
   In addition to the increased disposal distance, haul road conditions are also a factor that contributes to the fuel ratio of hauling overburden material. The results of the field measurements in the table above concluded that the total average actual score of the overburden road was 25.80 below the baseline score of 27.00.
c. Disposal Condition
   Company and contractor representatives conducted a joint inspection of the disposal conditions. The two parties, namely the company representative and the contractor, then determine the actual and agreed value and sign for the minutes of the inspection results. Total average score is 68.72 below the standard 80.

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d. Operator Abuse

The results of observation conducted on dump truck operators carried out every week found that there were still operators who did not follow the procedure or there was abuse by operators in operating dump trucks. There is still operator misuse in operating the unit. Total operator abuse since January 2022 – June 2023 is 207 and total participant 12,865. So the impact on the actual fuel ratio is also very small.

e. Dump Truck Speed

The recorded dump truck speed is the average speed in 1 (one) cycle, starting from the dump truck being fully loaded by the digger - travelling to the disposal site - manouvering when dumping material - travelling back to the loading point - queuing at the loading point. From the figure below, it can be seen that the longer the distance from the loading point to the disposal, the lower the average speed of the dump truck and vice versa.The higher the average speed of the dump truck when compared to the short disposal distance so that it will save fuel.

Figure 4. Actual Distance vs Speed Jan 2022 – June 2023

3.3. Loading Overburden

Actual fuel ratio of big diggers 0.25 Liter/bcm is slightly higher than fuel ratio plan or budget 0.23 Liter/bcm that can be seen on figure 3 above.

a. Loading Point Condition

Similar to the assessment of road conditions and disposal conditions, the assessment of loading point conditions was also conducted joint inspection between company and contractor representatives. The two parties then determine the actual and agreed value and sign for the minutes of the inspection results. Total average score is 55.35 below the standard 80

a. Big Digger Productivity

From the available data, all diggers produce productivity below the plan or budget. Below is actual the productivity of all big diggers compare to plan or budget.

Productivity

Month	Komatsu PC3000	Hitachi EX2600	Hitachi EX2500	Komatsu PC2000	Komatsu PC1250	Komatsu PC3000	Hitachi EX2600	Hitachi EX2500	Komatsu PC2000	Komatsu PC1250
	Budget	Budget	Budget	Budget	Budget	Actual	Actual	Actual	Actual	Actual
AVERAGE	930	1,110	640	757	397	724	985	580	496	248

Figure 5. Productivity All Big Diggers

Low productivity of all diggers caused by many factors. The table below is the percentage of factors causing low productivity that are the biggest from the weekly data record recapitulation received by the company from the contractor. In addition to the 4 (Four) major factors below there are still many other factors, namely the shortage of dump trucks by 5.4%, geological issues (material inserts) 5.6%. The author only highlights these 4 factors as factors that contribute greatly to digger productivity. As for haul road conditions, 21.1% are factors in the overburden hauling activities described above. The four factors are shown in the table below.

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Contribution	Percentage
Haul road condition	21.10%
Preparation loading point	19.89%
Top loading or double bench	13.27%
Spotting time loading point	12.34%
Pad loading while loading soft material	11.39%
Disposal condition	6.08%
Geologycal issues	5.67%
Lack of dump truck	5.43%
Crowded	4.84%
Total	**100.00%**

Figure 6. Low productivity factor

3.4. Hauling Coal Mine

The dump truck used to transport the coal is same with using to transport overburden with additional cover on edge of the vessel of Komatsu HD-785. From the company data, actual fuel ratio is 1.34 Liter/bcm or 4.76 % higher than plan 1.28 Liter/bcm that can be seen in the table below. The biggest factor in the increase in fuel ratio in coal hauling activities is the addition of mileage from the loading point to the crusher, this can be seen in the figure below where weighted average distance actual is 11.28 Km compared to plan only 10. 65 Km.

In this analysis phase, the author has identified the root cause of the high fuel ratio.

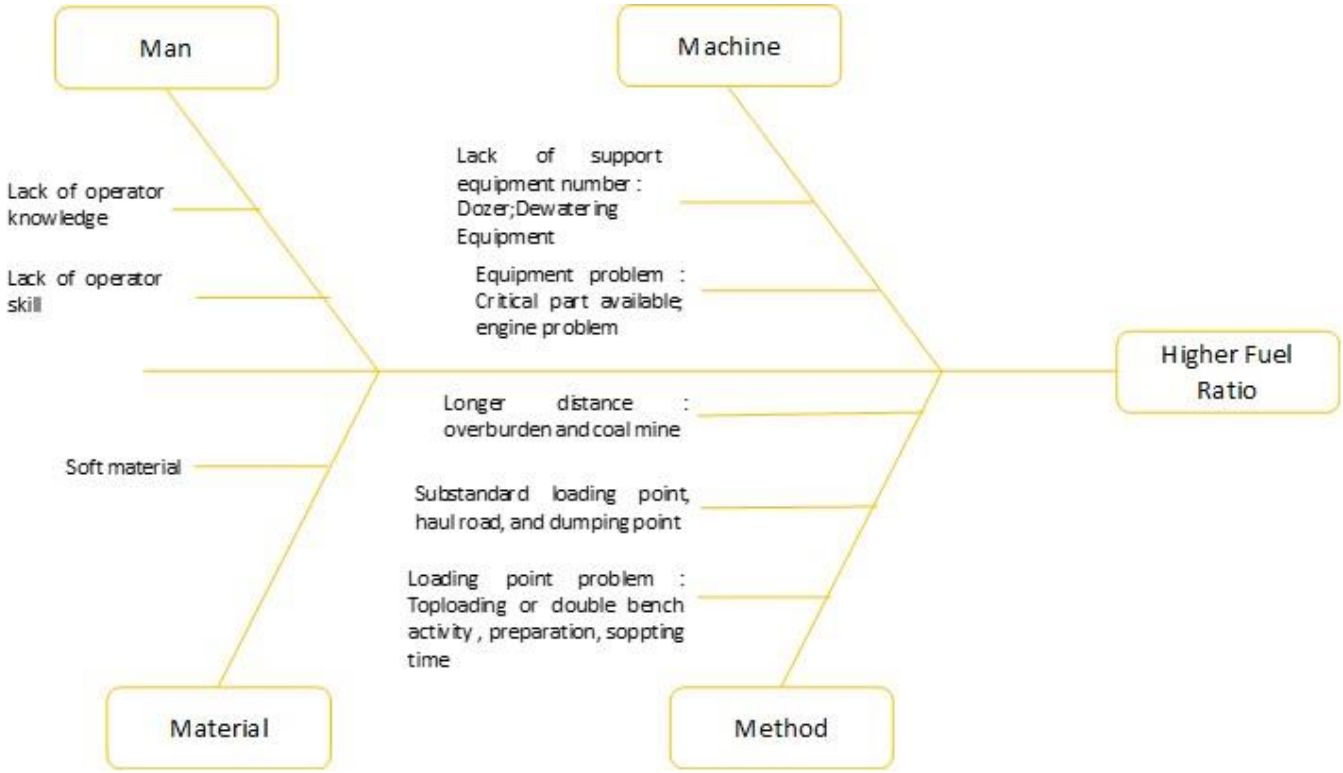

Figure 7. Fishbone diagram
(**Source :** Author)

Total actual cost for all mining activities is US$ 134.05 million or 27% higher than plan of US$ 105.00 million.

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4. Improve Phase

At this improve phase, the author and project team members that includes from company and contractor representative conducted discussion regularly to find solution to root causes that being identified.

Category	Root Causes	Status
Man	Lack of operator and supervisor knowledge	Controllable
	Lack of operator and supervisor skill	Controllable
Machine	Lack of support equipment number : Dozer, Dewatering Equipment	Controllable
	Equipment problem : Critical part availability, Engine problem	Controllable
Method	Longer distance overburden and coal mine	Controllable
	Substandard loading point, haul road, and dumping point	Controllable
	Loading point problem : Toploading or double bench, preparation, spotting time	Controllable
Material	Soft material	Controllable

Figure 8. Table of Root Causes
(**Source:** Author)

All of the main causes listed above may be managed, allowing the fuel improvement team's corrective action plan based on the discussion outcomes to be implemented in the field. The team prioritized each root cause based on the aspects that had the greatest impact on the increase in fuel ratio. The following are prioritized based on the effectiveness of the implementation and the time limit, with a weekly assessment of the action plan implemented.

First Priority:

- Lack of knowledge of operator and supervisor become the first priority since it affects operational efficiency, as a lack of information regarding fuel ratio can lead to inefficient fuel use.
- The first priority is to identify equipment problems linked to key part availability and engine problems, as they might create operational downtime. Engine problems can lead to protracted operational downtime, resulting in considerable financial losses for the organization.
- Determination of overburden and coal mine distance as the first priority due to longer distance overburden and coal mines typically involve substantial reserves of coal and significant investment opportunities with favorable cost-to-benefit ratios.

Second Priority:

- Prioritizing the lack of operator and supervisor skills as the second priority due to ensure long-term effectiveness and efficiency of operations relies heavily on the skills and competency of the workforce.
- Prioritizing the lack of support equipment such as dozers and dewatering equipment as the second priority can be justified by considering impact on operations.
- Prioritizing the substandard loading point, haul road, and dumping point as the second priority due to while substandard loading, haul, and dumping points pose risks to personnel and equipment, immediate safety hazards associated with critical equipment failures or process deficiencies may require more urgent attention.
- Prioritizing the loading point problems such as toploading or double bench, preparation, and spotting time as the second priority due to depend on situation and material.
- In mining operations, soft materials become second priority for several reasons related to the practicalities and safety of extracting valuable resources.

Based on priority on corrective action plan subscribed above, recommendations can be summarized below

1. First Priority:

1.1. Lack of operator and supervisor knowledge:

- Conduct detailed assessment for operator and supervisor where they are lacking of knowledge area.

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- Review training needs analysis (TNA) for operator and supervisor.

1.2. Equipment problem: Critical part availability, Engine problem:

- Identify the specific critical part(s) that are currently lacking and causing disruptions in operations.
- Analyze historical data and current usage patterns to understand the demand for the critical part(s) and consult with relevant stakeholders to ascertain the frequency and urgency of need.

1.3. Longer distance overburden and coal mine

- Conduct a comprehensive analysis of the mining site layout and topography to identify opportunities for optimizing haul.
- Develop optimized haul routes that minimize the distance and consider factors.

2. Second Priority:

2.1. Lack of operator and supervisor skill

- Conduct a comprehensive assessment of current operator and supervisor skills and competency.
- Review training needs analysis (TNA) for operator and supervisor.

2.2. Lack of support equipment number: Dozer, Dewatering Equipment

- Conduct a comprehensive review of ongoing and upcoming projects to identify the specific requirements for dozer and dewatering equipment.
- Research potential suppliers and rental companies for dozers and dewatering equipment.

2.3. Substandard loading point, haul road, and dumping point

- Conduct inspection of the loading point, haul road, and dumping point to identify deficiencies and safety hazards.

2.4. Loading point problem: Top-loading or double bench, preparation, spotting time

- Conduct a thorough assessment of the loading point layout, including topography, bench configuration, and geological conditions.

2.5. Soft material

- Conduct a detailed analysis of the soft material properties, including density, moisture content, cohesion, and shear strength.
- Prepare the loading point by leveling the ground, reinforcing weak areas, and installing stabilization measures (e.g., geotextiles, aggregate base) to improve traction and stability.

5. Control Phase

To ensure that the priority on improve phase has implemented, team has made discussion and take steps such conduct regular weekly and monthly audit and inspection through On Spot Monitoring (OSM) and Planned Task Observation (PTO) involves the company and contractor representatives. Both results of OSM and PTO are recorded and published to company and contractor management. Both representatives will be monitored the corrective action plan. Another control from both parties are conduct weekly regular meeting to summarizing progress and identifying area of improvement and implement corrective actions promptly when deviations are identified

5.1. Implementation Plan

Based on proposed solution in improve phase, detail implementation plan related to priority can be carried out as follows:

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Category	Priority	Area to be improved	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23
Lack of operator and supervisor knowledge & Skill	1	Conduct detailed assessment for operator and supervisor where they are lack of knowledge, skill, and competency area						
		Review training needs analysis (TNA) for operator and supervisor						
Equipment problem : Critical part availability, Engine problem	1	Identify the specific critical part(s) that are currently lacking and causing disruptions in operations						
		Analyze historical data and current usage patterns to understand the demand for the critical part(s) and consult with relevant stakeholders to ascertain the frequency and urgency of need.						
Longer distance overburden and coal mine	1	Conduct a comprehensive analysis of the mining site layout and topography to identify opportunities for optimizing haul routes						
		Develop optimized haul routes that minimize the distance and consider factors						
Lack of support equipment number : Dozer, Dewatering Equipment	2	Conduct a comprehensive review of ongoing and upcoming projects to identify the specific requirements for dozer and dewatering equipment.						
		Research potential suppliers and rental companies for dozers and dewatering equipment.						
Substandard loading point, haul road, and dumping point	2	Conduct inspection of the loading point, haul road, and dumping point to identify deficiencies and safety hazards.						
Loading point problem : Toploading or double bench, preparation, spotting time	2	Conduct assessment of the loading point layout, including topography, bench configuration, and geological conditions.						
Soft material	2	Conduct a detailed analysis of the soft material properties, including density, moisture content, cohesion, and shear strength.						
		Prepare the loading point by leveling the ground, reinforcing weak areas, and installing stabilization measures (e.g., geotextiles, aggregate base) to improve traction and stability.	Depend on actual condition					

Figure 9. Implementation Schedule
(**Source:** Author)

First priority implementation plan will be start on July 2023 to December 2023.

- Assessment for operator and supervisor including new hire (if any) will be taken 2 months includes employees who are not working and on leave. The schedule within 2 months has already include review training needs analysis or TNA.
- Specific critical parts including review historical data and current usage of the parts will take time 2 months to complete. This also includes recommendations to management for review and cost allocation.
- Analysis of site conditions and topography to find optimal road routing can be done over a period of 6 months. This time interval includes a monthly review of actual distances against the mining plan and sequence to look for opportunities for new routes or shorter road segment changes such as bend changes.

Second priority implementation plan will be start on July 2023 to December 2023.

- Lack of support equipment for dozer and dewatering equipment review will take 1 month. However, management review and option whether it needs to rent or purchase will take time 4 months including tender process.
- Conduct regular inspection of the loading point, haul road, and dumping point to identify deficiencies and safety hazards will be done every month by both representatives.
- Conduct assessment of the loading point layout, including topography, bench configuration, and geological conditions will be done every month by both representatives.
- Analysis soft material properties will take 1 month and preparation of loading point ground, reinforce weak area will depend on actual conditions.

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CONCLUSION AND RECOMMENDATION

Conclusion

The content of the conclusions in this chapter is to answer the research question. Below is the research question that is answered from the analysis:

1. What are the factors that affect high fuel ratio in the mining contractor?

Actual high fuel ratio from January 2022 – June 2023 based on investigations conducted by the author, there are 3 (three) major factors from all mining activities carried out by the contractor that contributed such as hauling overburden, loading overburden, and hauling coal mine.

2. What is the best scenario to reduce fuel ratio?

To overcome the major factors, author make priority business solution that can be implemented or done to reduce or lower the high fuel ratio are based as follows:

2.1. First Priority:

a. Lack of operator and supervisor knowledge:
   - Conduct detailed assessment for operator and supervisor where they are lacking of knowledge area.
   - Review training needs analysis (TNA) for operator and supervisor.

b. Equipment problem: Critical part availability, Engine problem:
   - Identify the specific critical part(s) that are currently lacking and causing disruptions in operations.
   - Analyze historical data and current usage patterns to understand the demand for the critical part(s) and consult with relevant stakeholders to ascertain the frequency and urgency of need.

c. Longer distance overburden and coal mine
   - Conduct a comprehensive analysis of the mining site layout and topography to identify opportunities for optimizing haul.
   - Develop optimized haul routes that minimize the distance and consider factors.

2.2. Second Priority:

a. Lack of operator and supervisor skill
   - Conduct a comprehensive assessment of current operator and supervisor skills and competency.
   - Review training needs analysis (TNA) for operator and supervisor.

b. Lack of support equipment number: Dozer, Dewatering Equipment
   - Conduct a comprehensive review of ongoing and upcoming projects to identify the specific requirements for dozer and dewatering equipment.
   - Research potential suppliers and rental companies for dozers and dewatering equipment.

c. Substandard loading point, haul road, and dumping point
   - Conduct inspection of the loading point, haul road, and dumping point to identify deficiencies and safety hazards.

d. Loading point problem: Top-loading or double bench, preparation, spotting time
   - Conduct a thorough assessment of the loading point layout, including topography, bench configuration, and geological conditions.

e. Soft material
   - Conduct a detailed analysis of the soft material properties, including density, moisture content, cohesion, and shear strength.
   - Prepare the loading point by leveling the ground, reinforcing weak areas, and installing stabilization measures (e.g., geotextiles, aggregate base) to improve traction and stability.

Recommendations

By developing implementation plan, both parties such as the company and contractor representatives can cooperate and understand the importance of implementing good mining practices in order to reduce fuel ratio and operational cost which will impact to both revenues. Implementation proposed solutions based on analysis, tangible and intangible resources are required for fuel ratio improvement in mining operations.

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Tangible resources:

1. Heavy Equipment Resources:
   - Onboard monitoring systems: Equipping haul trucks with real-time fuel consumption monitors and route optimization software allows for adjustments to driving habits and haul routes for better fuel efficiency.
   - Tire management programs: Implementing a comprehensive tire management program that includes regular inspection, inflation pressure monitoring, and retreading can extend tire life and reduce rolling resistance, leading to improved fuel economy.
   - Idle reduction technology: Installing automatic engine shutoff systems for haul trucks that are idling for extended periods can significantly reduce fuel waste.
2. Operational Resources:
   - Fleet management software: Utilizing software that tracks haul truck location, speed, and fuel consumption allows for better planning of routes, dispatching, and identifying fuel-wasting practices.
   - Road maintenance: Regularly maintaining haul roads by minimizing potholes and grading for smoother surfaces reduces rolling resistance and improves fuel efficiency for vehicles.
3. Training and Awareness:
   - Fuel-efficient driving training: Training haul truck operators on fuel-efficient driving techniques like smooth acceleration, maintaining optimal speeds, and avoiding unnecessary idling can significantly improve fuel ratio.
   - Fuel awareness campaigns: Educate and incentivize employees on the importance of fuel efficiency through workshops, competitions, and recognition programs.

Intangible resources:

1. Company Culture and Mindset:
   - Focus on fuel efficiency: Embed fuel efficiency as a core value within the company culture.
   - Data-driven decision making: Foster a culture of data analysis and utilization. Regularly monitor fuel consumption data, identify trends, and use it to make informed decisions about resource allocation, maintenance schedules, and route optimization.
   - Continuous improvement: Develop a culture of continuous improvement by encouraging employees to suggest ways to optimize fuel usage.
2. Knowledge and Expertise:
   - Develop internal expertise: Invest in training programs to develop in-house expertise on fuel-efficient technologies, driving techniques, and operational best practices.
   - Benchmarking and knowledge sharing: Participate in industry forums, conferences, and benchmarking exercises to learn from other successful mining operations' fuel-saving strategies.
   - Collaboration with equipment manufacturers: Work closely with equipment manufacturers to understand the latest fuel-efficient technologies and best practices for operating their machinery.
3. Planning and Optimization:
   - Route optimization: Utilize software and data analysis to meticulously plan haul routes for minimal distance, traffic avoidance, and optimal utilization of haul trucks.
   - Shift scheduling and workload distribution: Optimize shift schedules and workloads to minimize empty haul truck trips and ensure efficient utilization of vehicles.
   - Predictive maintenance: Implement preventative maintenance programs to identify potential equipment issues before they arise.
4. Incentives and Recognition:
   - Driver recognition programs: Establish reward systems that recognize and incentivize haul truck operators who demonstrate fuel-efficient driving practices.
   - Departmental fuel-saving competitions: Organize competitions between departments to encourage collaboration and friendly competition in achieving better fuel efficiency.

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- Performance-based bonuses: Link bonuses for management and supervisors to achieving fuel efficiency goals alongside other performance metrics.

Recommendations and future opportunities are to implement this project improvement in another pit with a similar issue, and it is expected that the organization will begin to routinely use the DMAIC method.

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Finally, it is my hope that this Final Project will benefit all readers greatly and make a positive impact on Indonesia mining firm and education.

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