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INCREASING OVERBURDEN PRODUCTIVITY ACHIEVEMENT BY USING LEAN SIX SIGMA FRAMEWORK: A CASE STUDY OF MINING ACTIVITY AT PT. BETA BY CONTRACTOR PT. DELTA

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Abstrak

PT. DELTA, sebagai salah satu kontraktor yang terlibat dalam kegiatan penambangan di PT. BETA, telah menunjukkan kinerja produksi lapisan batuan penutup yang kurang optimal selama satu tahun terakhir. Selama periode satu tahun terakhir (Januari 2023 hingga Desember 2023), kinerja produksi lapisan batuan penutup PT. DELTA seringkali berada di bawah rencana (target). Proyek Akhir ini menggali aplikasi metodologi *Lean Six Sigma* untuk meningkatkan produktivitas lapisan batuan penutup dalam kegiatan penambangan yang dilakukan oleh PT. DELTA. Tujuan utama dari Proyek Akhir ini adalah untuk menyelidiki dengan cermat aktivitas penambangan di PT. DELTA dan menilai bagaimana prinsip-prinsip *Lean Six Sigma* dapat digunakan secara strategis untuk meningkatkan efisiensi dan produktivitas dalam proses pengangkatan lapisan batuan penutup. Aspek signifikan yang diperiksa adalah identifikasi dan eliminasi aktivitas yang tidak menambah nilai dan berkontribusi pada waktu pengangkatan lapisan batuan penutup yang berkepanjangan. Kerangka kerja DMAIC (*Define, Measure, Analyze, Improve, Control*), yang merupakan bagian integral dari *Lean Six Sigma*, memandu pendekatan yang sistematis dan berbasis data yang diadopsi sepanjang penelitian. Dengan mengusulkan dan mengimplementasikan perbaikan yang ditargetkan, penelitian bertujuan untuk menunjukkan dampak nyata yang dapat dimiliki oleh metodologi *Lean Six Sigma* dalam meningkatkan produktivitas.

Kata Kunci: batuan penutup; peningkatan produksi; *lean Six Sigma*; DMAIC

Abstract

PT. DELTA, as one of the contractors engaged in mining activities at PT. BETA, has exhibited suboptimal overburden production performance over the past year. During the last one-year period (January 2023 to December 2023), PT. DELTA's overburden production performance is often below the plan (target). This Final Project delves into the application of Lean Six Sigma methodologies to augment overburden productivity in the mining operations conducted by PT. DELTA. The primary objective of this Final Project is to meticulously examine the mining activities at PT. DELTA and assess how Lean Six Sigma principles can be strategically employed to enhance efficiency and productivity in overburden removal processes. A significant facet under scrutiny is the identification and elimination of non-value-added activities that contribute to prolonged overburden removal times. The DMAIC (Define, Measure, Analyze, Improve, Control) framework, inherent to Lean Six Sigma, guides the systematic and data-driven approach adopted throughout the study.By proposing and implementing targeted improvements, the study aims to showcase the tangible impact that Lean Six Sigma methodologies can have on increasing productivity.

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INTRODUCTION

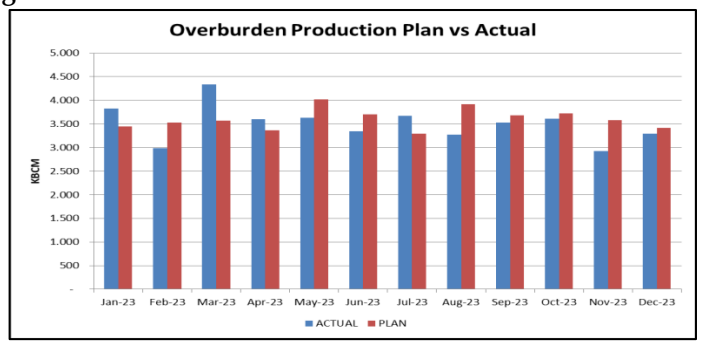
PT. BETA is a coal mining company in East Kalimantan that implements open-pit mining activities. At PT. BETA, coal mining activities are carried out in two divisions. First, there are mining activities carried out by PT. BETA itself. PT. BETA has its team and resources that are responsible for carrying out mining activities. This activity is under the Mining Operations Division. Second, another part of mining activities is carried out by external contractors. PT. BETA works with several contractors to carry out various aspects of mining. Mining activities carried out by the contractors are under the supervision of PT. BETA Contract Mining Division. By involving contractors, PT. BETA can increase its operational capacity and efficiency.

PT. DELTA is one of the contractors involved in mining activities at PT. BETA. Since early 2022, PT. DELTA has conducted mining operations at one of PT. BETA's pit. All activities carried out by PT. DELTA has determined its target by PT. BETA. PT. DELTA conducts operational planning according to predetermined targets. Once the plans are prepared, the plans and targets will be reviewed by both parties to ensure suitability and feasibility. After going through the review and agreement process, the plan and targets will become guidelines for PT. DELTA in conducting mining activities. During the operational process, PT. BETA will monitor and review the progress achieved by PT. DELTA regularly.

Periodic monitoring and review are essential to ensure mining activities are still on track according to predetermined targets (Agboola et al. 2020). Corrective or adjustment actions can be taken if there is a discrepancy or a change in conditions to achieve the set targets. By efficiently identifying non-conformities, analyzing their causes, implementing corrective actions, and continuously improving, mining operations can reduce the impact of changing conditions and ensure that predetermined targets are achieved. This is undoubtedly a challenge for PT. DELTA in conducting mining activities. About how PT. DELTA can ensure that mining activities can be aligned with the plan so that the actual achievements can meet the targets that have been planned.

During the last one-year period (January 2023 to December 2023), PT. DELTA's overburden production performance is often below the plan (target). Based on Figure 1, the overburden production performance fluctuates during the period January 2023 - December 2023. If this problem is not resolved immediately, it will have long-term implications for PT. BETA targets achievement, as outlined in the company's annual Work Plan and Budget (RKAB), which is submitted to and approved by the Ministry of Energy and Mineral Resources (ESDM) or The Authorized agency delegated by the Ministry of Energy and Mineral Resources.

Figure 1. Overburden Production Performance Plan vs. Actual



Source: by Author

Overburden production targets that are not achieved will also hinder the progress of the development of the pit, which in turn will affect the mining plans that have been set previously. This problem will impact the pre-planned targets, causing an adverse effect on the company's revenue. It is critical to immediately remedy the situation and ensure that overburden production aligns with the set targets. Thus, the company can secure its revenue and maintain its operational efficiency.

RESEARCH METHODS

A. Data Collection Method

To analyze the actual conditions, field observation such as on spot monitoring can be carried out (primary data). Field observations provide an opportunity to identify substandard activities during the overburden stripping process (Nugraha and Yudoko 2020).

Analyzing the data collected through field observations makes it possible to identify the main root cause of the underperformance issue. This can be achieved through data analysis techniques and focus group discussions. These discussions involve bringing together relevant stakeholders and experts to deliberate on the observed issues, share insights, and collectively arrive at conclusions regarding the main contributing factor to the problem.

Through this comprehensive approach of data analysis, field observations, and focus group discussions, a better understanding of the reasons behind the underperformance of overburden production can be gained. This knowledge will serve as a foundation for developing effective strategies and implementing necessary improvements to address the identified root cause and enhance productivity in the future.

B. Data Analysis Method

To determine the primary cause behind the underperformance of overburden production with the predetermined targets, a comprehensive analysis of data and observations at each stage of the operation is necessary. The measurement process

involves examining the previous baseline conditions by analyzing production data over one year from January 2023 to December 2023, which is obtained from weekly and monthly reports (secondary data).

After conducting field observations, quantitative data obtained, including instances of substandard activities during the overburden stripping process, can be presented as a Pareto diagram using Excel. The first step in creating the Pareto diagram involves identifying the frequency of occurrence for each problem observed within a specific period. Once the frequency of occurrence for each problem is determined, the next step is to group these problems based on their respective frequencies. This grouping enables a better understanding of the distribution of issues and highlights the most significant ones.

To enhance the analysis, it is important to calculate the cumulative frequency and percentage for each problem group. Cumulative frequency denotes the total occurrence of problems up to a particular group, while the percentage represents the cumulative frequency proportion to the total frequency of all problems. These calculations provide valuable insights into the relative impact and importance of each problem group with the overall observation data.

By presenting the data in a Pareto diagram, which displays the problems in descending order of their frequencies, it becomes visually apparent which problems have the greatest occurrence and hence the highest impact. This graphical representation aids in prioritizing efforts and resources towards addressing the most critical issues that contribute to the underperformance of overburden production.

Root Cause Analysis is a valuable tool for identifying major or significant discrepancies in a process or system. Among the various methods available, one approach commonly used is the fishbone analysis method. Fishbone diagrams, also known as Ishikawa diagrams or cause-and-effect diagrams, are a powerful diagnostic tool for conducting root cause analysis and visualizing the factors contributing to a problem. They are particularly beneficial in service improvement projects where understanding the underlying causes is crucial.

In this case, quantitative data obtained from field observations will be analyzed using fishbone analysis. Focus group discussion is also needed to determine the root causes. By systematically examining various categories or branches of the fishbone diagram, such as equipment, processes, people, environment, and management, the analysis aims to uncover the root causes behind the underperformance overburden issue. The focus group discussions are a valuable platform for sharing and discussing the data collected during the field observations, allowing experts and stakeholders to provide their insights and perspectives. The experts and stakeholders consist of engineers from PT. BETA and PT. DELTA along with the engineering section head. Focus group discussions will involve several experts and stakeholders as stated in the Table 1 below:

Table 1. FGD Experts and Stakeholders

Position	Company	Number	Work Experience
Production Engineer	PT. DELTA	2	> 2 years
Mine Plan Engineer	PT. DELTA	2	> 2 years
Section Head	PT. DELTA	1	> 2 years
Engineer	PT. BETA	3	> 2 years
Superintendent Operation	PT. BETA	1	> 2 years

Source: by Author

The questions during the focus group discussion will be the same for all experts and stakeholders and the data obtained from the field observations are thoroughly examined and analyzed within the context of the identified root causes. By collectively exploring the data and considering the knowledge and expertise of the participants, the focus group discussions contribute to a comprehensive understanding of the deviations and their potential impact on the overburden production process. The study can comprehensively examine and understand the intricate interrelationships among different factors affecting overburden production by employing fishbone analysis. This method enables a structured and organized exploration of potential causes, identifying key areas that require attention and improvement.

Fishbone analysis is a valuable technique for conducting detailed investigations into the factors contributing to unachieved overburden production. Its systematic approach helps unravel the root causes, providing valuable insights that can inform targeted interventions and improvements to enhance overall productivity.

RESULT AND DISCUSSION

A. Define Phase

In this phase, the goal is to articulate the identified challenge, stemming from a business issue, and assemble a dedicated team to tackle the problem head-on. The Define phase encompasses:

1. Project team forming which is composed of the project sponsor, project champion, project leader, and project members.
2. The opportunity was to reduce losses during overburden removal and increase overburden production.
3. Voice of Customer. The customers of this project were PT. BETA team.
4. Project Scope. The details of the project scopes can be seen in Table 2 below

Table 2. Project Scopes

Parameter	In Scope	Out of Scope
Area	PT. DELTA Mining Area (PT. BETA site)	Other mining area in PT. BETA
Task sequence	Overburden activities only (overburden removal)	Before and after overburden removal activity such as clearing, topsoiling, and coal getting
Discussion boundary	Focuses on the proposed solutions to improve the overburden production performance.	Other discussion outside of overburden performance problem

Source: by Author

To overcome the existing problems, The Author formed a project charter by forming a team to make a continuous improvement.

Figure 2. Project Charter

PROJECT CHARTER	
Data	
Project Name: Increasing Productivity Achievement at PT. Beta by Contractor PT. Delta Key area(s) to be improved Overburden production	Sponsor : PT. DELTA & PT. BETA Management Champion : PT. BETA Supt. Operation PT. BETA Section Head Project Leader : Dinda Ratna Mudya Project Member : 2 of PT. DELTA Production Engineer 2 of PT. DELTA Mine Plan Engineer 3 of PT. BETA Engineer
Opportunity / Problem Statement	
What is happening?	PT. DELTA's overburden production performance has often below the plan.
When did the problem start?	Since February 2023
Where is the problem occuring?	At overburden removal stages
Who is experiencing the pain?	PT. DELTA and PT. BETA Management
Business Impact	
What is the quantified value creation of project	Reduce losses during overburden removal and increase overburden production
Key Metrics	
What is the improvement objective and target?	To improve the actual overburden production performance of PT. DELTA.
Project Scope	
Area Task Sequence Disscussion Boundary	PT. DELTA Mining Area Overburden activities only Focuses on the proposed solutions to improve the overburden production performance.
Project Plan	
Define	Aug-23
Measure	Oct-23
Analysis	Nov-23
Improve	Jan-24
Control	Jan-24

Source: by Author

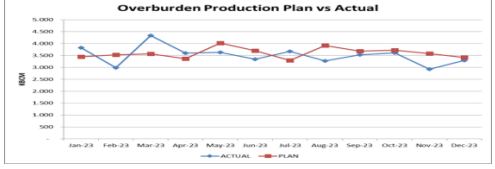
B. Measure Phase

The purpose of this phase is to comprehend and gain insights into parameters influencing performance. The Measure Phase encompasses:

1. Determine Measurement Parameters. The data would be measured for this project were monthly overburden production, loader cycle time, and field condition problems.
2. Determine Measurement System. The project team will use data from daily and monthly report monitoring.
3. Data Collection & Determine Baseline. Overburden production data will be collected daily and it will be summarized at the end of the month. Cycle time loader data will be collected at various loading points on several days. Field observation data collection through on-spot monitoring is also necessary to identify any constraints that occur during the overburden removal process. This data is recorded and collected by engineers or each supervisor daily.

Based on the data, during the last one-year period (January 2023 to December 2023), PT. DELTA's overburden production performance is often below the plan (target). This is not ideal because it occurs repeatedly, and as known, every month the production target is always determined by the company through mutual agreement.

Figure 3. Overburden Production Graph



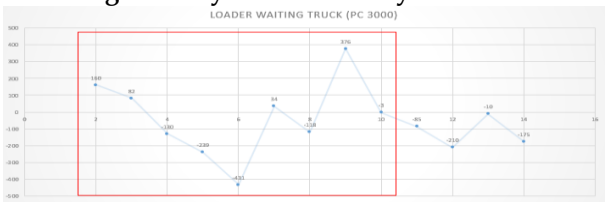
Source: by Author

C. Analyse Phase

Based on data collection from loader cycle time and field observation, 3 problems related to OB production have been identified. These problems are hauler delay, loader productivity is not achieved, and loader delay. These hauler and loader delays can disrupt the smooth flow of overburden removal, leading to a decrease in overall mining efficiency. It's also can contribute to project timeline delays, affecting the overall schedule for the mining operation. Loader productivity that is not achieved can also influence OB production. If loaders consistently fail to achieve the required productivity levels, the mining operation may struggle to meet production targets. This can have financial repercussions, especially if contractual obligations or market demands are not fulfilled.

The sample of loader productivity analysis based on cycle time data can be seen in Figure 4 below. Positive values indicate the loader waiting for the hauler, while negative values indicate the hauler queuing at the loading point. The increasing idle time contributes to a decrease in productivity.

Figure 4. Cycle Time Analysis Result



Source: by Author

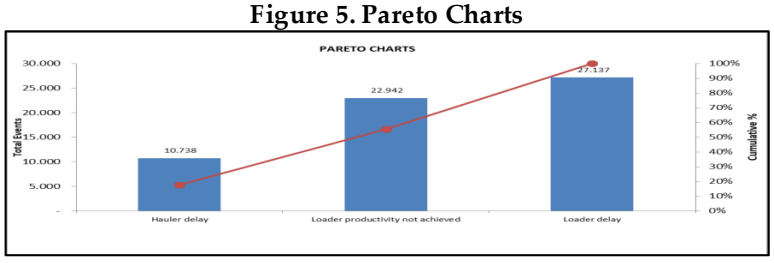
From Table 3 and Figure 5, we can see the percentages of problems that have an impact on overburden productivity problems based on cycle time analysis and field observation. Based on the data we can see that loader delay is the main cause for this problem.

Table 3. Project Descriptions and Percentages

No.	Problem Descriptions	Total Events	Percentages
1.	Hauler delay	10.738	18%
2.	Loader productivity not achieved	22.942	38%
3.	Loader delay	27.137	45%
TOTAL		**60.817**	**100%**

Source: by Author

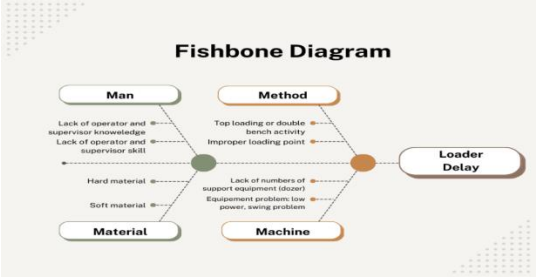
Figure 5. Pareto Charts



Source: by Author

Root Cause Analysis (RCA) serves as a method for pinpointing the underlying factors contributing to a significant deviation. The outcomes of RCA are utilized to steer adjustments in processes, the environment, and human behavior, aiming to mitigate or prevent similar deviations in the future. Utilizing techniques like fishbone analysis, the root cause method is employed to systematically address the issues that have occurred. At this Phase, The Author looks for the root cause of the loader delay over problem.

Figure 6. Fishbone Diagram



Source: by Author

Based on Root Cause Analysis (RCA) using the Fishbone Diagram, The Author found several root causes that caused problems in loader delay which had an impact on overburden production. Lack of operator and supervisor knowledge and skill, top loading or double bench activity, improper loading point, hard material, soft material, lack of support equipment, and other equipment problems are the causes of loader delay.

This issue is also reflected in the results of the field observations that have been conducted. Such as the field observation on July, 7th 2023 (Figure 7), which indicated the presence of top loading and double bench activities in the overburden loading point area.

Figure 7. Field Observation

Source: by Author

D. Improve Phase

In this phase, The Author as a team leader and team members discusses for the possible solutions to root causes that were found in.

Table 4. Root Cause Analysis

Categories	Root Causes	Controllability
Man	Lack of operator and supervisor knowledge	Controllable
	Lack of operator and supervisor skill	Controllable
Method	Top loading or double bench activity	Controllable
	Improper loading point	Controllable
Material	Hard material	Controllable
	Soft material	Controllable
Machine	Lack of number of support equipment (dozer)	Controllable
	Equipment problem: low power, swing problem	Controllable

Source: by Author

Based on the discussion from Table 4 above, all root causes are controllable, so there should be no difficulty in handling the root causes. This includes the hard and soft materials problem, which can also be controlled if identified early and the handling is properly planned. The corrective action plan is also made based on the results of discussions with team members and determining priorities based on problems which according to the results of the discussion have a big impact on overburden production.

Based on the discussion, in Table 4 priority is determined based on the effectiveness and timeliness of the corrective action plan's execution. Priority 1 implies that corrective actions can be executed immediately or within 3 – 4 days, priority 2 suggests they can be implemented within 1 week, and priority 3 indicates that the corrective actions require more than 1 week to be carried out (need future discussion or trial and error). In implementing the action plan, the involvement of engineers from PT. BETA & PT. DELTA is crucial, as well as the participation of production and management teams. This collaboration is essential to achieve the desired improvement.

Table 5. Corrective Action Plan

Categories	Root Causes	Corrective Action Plans	Priority	PIC
Man	Lack of operator and supervisor knowledge	Increase awareness among all personnel	1st	PT. BETA & PT. DELTA
	Lack of operator and supervisor skill	Provide targeted training	2nd	PT. BETA & PT. DELTA
Method	Top loading or double bench activity	Conduct a comprehensive review or inspection of existing loading procedures	1st	PT. BETA & PT. DELTA
	Improper loading point			
Material	Hard material	Fullfillment inventory broken material by improve the blasting design	3rd	PT. BETA & PT. DELTA
	Soft material	Continuous supply of pad material with a clustering system	2nd	PT. DELTA
Machine	Lack of number of support equipment (dozer)	Fullfillment of dozer availability	1st	PT. DELTA
	Equipment problem: low power, swing problem	Accelerate repair, find for a backup equipment	2nd	PT. DELTA

Source: by Author

Based on the corrective action plan, the recommended solutions are summarized below:

1. PT. BETA and PT. DELTA team would increase awareness among all personnel (operator and supervisor) and provide targeted training.
2. PT. BETA and PT. DELTA team would provide targeted training to the operator and supervisor.

3. PT. BETA and PT. DELTA team would conduct a comprehensive review or inspection of existing loading procedures.
4. PT. BETA and PT. DELTA team would fulfill inventory broken material by improving the blasting design for the hard material problem.
5. PT. DELTA would do a continuous supply of pad material with a clustering system for the soft material problem.
6. PT. DELTA would fulfill the need for a dozer and accelerate repair.

E. Control Phase

The next phase is the control phase. Control is necessary to assess the smooth implementation of the improvement, allowing for tracking and optimization over time. Based on the Focus Group Discussion, monitoring improvements can be carried out through on-site observations, utilizing On Spot Monitoring (OSM) activities periodically by representatives from PT. BETA, accompanied by representatives from PT. DELTA. This is essential to ensure the alignment of improvement progress in the field with the initial plan.

The results of the OSM will be recorded and published to the management of both companies. Additional control activities can be conducted during the weekly meetings at the beginning of each week. In these meetings, PT. DELTA can present the progress of improvement and weekly production reports, as well as highlight any challenges encountered in the improvement process. This allows for collaborative discussions with representatives from PT. BETA to find the best solutions. The format for On Spot Monitoring can be seen at Table 6. below.

Table 6. On Spot Monitoring Form

ON SPOT MONITORING

Custodian	:	Lead Inspector	:
Contractor	:	Representative	:
Location	:	Number of OSM	:
Date	:		

NO	PHOTO	FINDING & RECOMMENDATIONS	ACTION BY	DUE DATE	% DONE
1.		Finding Reccomendation			
2.		Finding Reccomendation			
3.		Finding Reccomendation			

Source: by Author

F. Implementation Plan & Justification

Based on the proposed corrective action plan at the improve stage, the details of the implementation plan based on the priority that will be carried out are as follows:

1. Increase awareness among all personnel by conducting regular toolbox talks focused on management loading procedures. These sessions can serve as

reminders and opportunities for questions or clarifications.
2. Conduct regular audits and inspections focused on management loading activities. This ensures compliance and identifies areas for improvement.
3. Implement an efficient shift planning system to ensure that dozers are utilized optimally.
4. Develop comprehensive training programs that specifically address management loading activities. This should include theoretical knowledge and practical exercises to ensure understanding and application.
5. For soft material problems, need a continuous supply of pad material with a clustering system by identifying and establishing material sources to ensure a continuous supply.
6. Implement a proactive and regular maintenance schedule for the dozer by conducting routine inspections, and preventive maintenance, and adhere to manufacturer-recommended servicing intervals to minimize unplanned downtime and have backup dozers available to cover for scheduled maintenance or unexpected breakdowns to ensure that loading operations can continue without significant disruptions.
7. For hard material problems, need fulfillment inventory broken material by improving the blasting design. This can be discussed with the blasting engineer of PT. BETA.

The implementation plan can be seen in Table 7 below.

Table 7. Implementation Schedule

Corrective Action Plans	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23
Increase awareness among all personnel						
Conduct a comprehensive review or inspection of existing loading procedures						
Fullfillment of dozer availability						
Provide targeted training						
Continuous supply of pad material with a clustering system	Based on actual field condition					
Accelerate repair, find for a backup equipment						
Fullfillment inventory broken material by improve the blasting design	By trial and error					

Source: by Author

The implementation plan for priority 1, aimed at improving awareness among all field personnel, including operators and supervisors, will be implemented in the first two months while monitoring progress in the field to assess any changes. Inspections of the loading point will be conducted at least twice a week, with regular reviews at the beginning of each week. Meanwhile, the fulfillment of dozers will be monitored daily. For priority 2, training activities will be conducted regularly every 3 months for new operators or supervisors (both recruits and those transferred from other sites) and for refresher sessions for some experienced operators or supervisors. The fulfillment of pad material will be adjusted based on the actual conditions of the presence of soft material

in the field. Additionally, a review of equipment performance improvement and the replenishment of backup equipment will be carried out once every 3 months. And for the handling of hard materials with improved blasting design, will be carried out gradually through a trial-and-error process while observing the conditions and requirements in the field.

CONCLUSION

The issues behind the actual overburden production performance of PT. DELTA often under a predefined plan are 3 which are hauler delay, loader productivity is not achieved, and loader delay. Based on the data, loader delay is the main cause of this problem.

To handle this problem, solutions or action items could be implemented to eliminate or minimize the chance of the problem occurring are: a) Increase awareness among all personnel, b) Conduct regular audits and inspections focused on management loading activities, c) Implement an efficient shift planning system to ensure that dozers are utilized optimally, d) Develop comprehensive training programs that specifically address management loading activities, e) For soft material problems, need a continuous supply of pad material with a clustering system by identifying and establishing material sources to ensure a continuous supply, f) Implement a proactive and regular maintenance schedule for the dozer by conducting routine inspections, and preventive maintenance, and adhere to manufacturer-recommended servicing intervals to minimize unplanned downtime and have backup dozers available to cover for scheduled maintenance or unexpected breakdowns to ensure that loading operations can continue without significant disruptions, g) For hard material problems, need fulfillment inventory broken material by improving the blasting design. This can be discussed with the blasting engineer of PT. BETA.

With the implementation of the plan, it is hoped that all relevant parties, both PT. BETA and PT. DELTA, can collaborate and understand the importance of implementing good mining practices, especially in overburden production. Additionally, they should comprehend how to handle issues in the field to enhance production following the planned targets. To implement the proposed improvement based on the analysis, tangible and intangible resources are needed. Tangible resources such as: 1) Heavy Equipment: good excavators, loaders, and haul trucks are essential for efficient overburden production in mining operations, 2) Infrastructure: well-maintained roads also contribute to the smooth movement of overburden materials within the mining site.

The intangible resources such as: 1) Mining expertise and knowledge: the collective knowledge and expertise of mining engineers, operators, and supervisors contribute intangible value to optimizing overburden production processes, 2) Operational strategies: effective planning, scheduling, and operational strategies that enhance the

overall efficiency of overburden production, 3) Data management systems: data management systems play a crucial role in monitoring and optimizing overburden production processes.

Recommendations and the next opportunities are to apply this project improvement in another pit that has a similar issue and it is expected that the company will begin to consistently utilize the Lean Six Sigma method.

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REFERENCES

Agboola, Oluranti et al. 2020. "A Review on the Impact of Mining Operation: Monitoring, Assessment and Management." *Results in Engineering* 8: 100181.

Cheusheva, Svetlana. (2023, March 16). How to create Pareto chart in Excel. https://www.ablebits.com/office-addins-blog/make-pareto-chart-excel/

Juaeni, Ahmad. (2020). Mining Operation Productivity Improvement by Using Lean Six Sigma Framework (Case: ASM Mine). [Master final project, Institut Teknologi Bandung]. School of Business and Management Final Project Data. https://fp-jkt.sbm.itb.ac.id/pdf/viewer.php?code=6hx4neo4kk4

Kesek, M. Bogacz, P. Migza, M. (2019).The Application of Lean Management and Six Sigma Tools in Global Mining Enterprises. IOP Conference Series: Earth and Environmental Science.

Nugraha, Arya, and Gatot Yudoko. 2020. "Statistical Process Control Implementation as Early Warning Signal for Safety Intervention Improvement at Mining Operation." *JEMIS (Journal of Engineering & Management in Industrial System)* 8(2): 32–55.

Tech Quality Pedia. (2020, March 20). What is a Fishbone Diagram? Ishikawa Diagram | Cause & Effect Diagram. https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death

Wahyudi, Petrus Tri. Yudoko, Gatot. (2019). Continuous Improvement of Drilling Ultra-Shallow Horizontal Well Through Lean Six Sigma Methodology. Journal Of Engineering and Management in Industrial System Vol. 7 No.2.