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A Structured Approach to Improve Production Process Performance in Operations of Coal Mining Business

Carin, Keanu Nathaniel Sofjan, Alden, Kingsley Gilbert, Windy Phangestu, Hesti Maheswari*
Management Study Program, Faculty of Business, School of Business and Economics, Universitas Prasetiya Mulya, Tangerang, Indonesia
*Corresponding author, email: hesti.maheswari@prasetiyamulya.ac.id

Abstract

In the coal mining industry, operational efficiency and production quality are critical to maintaining competitiveness and meeting growing energy demands. This study focuses on the implementation of quality tools to optimize cycle time within the coal production process, from extraction to final delivery to consumers. The tools utilized include flowchart, check sheet, fishbone diagram, Pareto chart, and control chart. The results showed that they are the most effective tools to solve the cycle time in coal mining industry and improve the quality of final products. A detailed workflow mapping revealed several critical bottlenecks contributing to inefficiencies, such as heavy rain, equipment breakdowns, loading delays, and inadequate interdepartmental coordination. Further root cause analysis using the Fishbone diagram identified key contributors from the environment, machinery, work methods, and management practices. The Pareto chart highlighted that a majority of delays were driven by a few dominant causes, consistent with the 80/20 principle, allowing the company to prioritize impactful improvement actions. The control chart, used to monitor cycle time, indicated the presence of special variations through out-of-control data points. These deviations signify the need for immediate investigation and corrective measures. As a result, the PDCA cycle is recommended as a sustainable improvement framework to address recurring inefficiencies and stabilize production performance. By integrating data-driven decision-making and continuous quality improvement, this study offers a strategic foundation for enhancing productivity and ensuring timely coal distribution, particularly for power generation and industrial sectors. The findings support a structured approach to quality management, contributing significantly to the resilience and sustainability of coal mining operations.

Keywords: cycle time, PDCA, quality tools

1. Introduction

In the competitive and challenging world of the coal mining industry, operational efficiency is one of the key indicators of success. A leading coal mining companies in Indonesia is also facing pressure to maintain optimal performance amid complex geographical conditions and fluctuations in global demand. One of the important aspects of measuring and improving operational efficiency is to analyze work cycle time. This cycle time reflects the total duration required to complete a cycle of coal production activities, from digging to delivery to customers. Cycle times that are too long or unstable can indicate inefficiencies in the production process (Gackowiec *et al.*, 2020). These inefficiencies can stem from a variety of factors, such as bad weather, machine breakdowns, queues at loading points, or poor coordination between work units (Saleh, Sulistianto and Aryanto, 2022). Therefore, it is important for companies to continuously monitor and analyze cycle time variations to identify the root cause of the problem and establish appropriate remedial strategies.

One of the systematic approaches that can be applied for this purpose is the use of quality control tools. The quality tools approach has long been used in the industry to help identify, analyze, and solve problems that affect quality and productivity (Ehrlinger and Wöß, 2022). In the context of cycle time control, some relevant tools include flowcharts, check sheets, pareto charts, fishbone diagrams, and control charts. Each tool has its own functions and benefits in analyzing processes and their variability. The combination of these tools can provide a comprehensive picture of the performance of the production process and the critical points that need more attention.

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Flowcharts are used to visually map the work process, allowing management to identify key stages and potential bottlenecks. Check sheets serve as a simple data collection tool, recording daily disturbances such as rain, equipment delays, or logistical constraints. The data from check sheets can be analyzed using a Pareto chart to prioritize dominant causes of inefficiencies. Control charts are then used to monitor the stability of the cycle time process over time. By calculating upper and lower control limits (UCL and LCL), companies can detect whether the process is statistically in control or has special variations that require corrective action (Yusniansyah and Kurniawan, 2023). These tools support data-driven quality control.

Several studies have also examined operational issues in mining activities. Kamari and Sugiyono (2020) emphasized that the effectiveness of coal crusher machines at PT MHU was still below target due to setup and equipment failure losses, which contributed to high downtime. Rafi and Witjaksana (2023) found mismatches between excavator productivity and dump truck capacity, leading to delays and underutilization. Aboelmagd (2018) applied linear programming to optimize equipment combinations in construction projects, showing cost efficiency but without considering process variation control. Although useful, most previous studies have focused on productivity analysis, cost optimization, or technical design, without integrating real-time process monitoring tools such as control charts for statistical stability evaluation. Quality is maintained from the time of selecting raw materials and the production process (Zacharias, 2022). It's too late to think about quality once the product is finished. Therefore, this research contributes by combining classical quality tools with the control chart method and integrating them into a continuous improvement framework using the PDCA (Plan-Do-Check-Act) cycle. This structured and data-driven approach is intended to not only identify but also monitor and reduce variations in cycle time in coal mining operations. Compared to earlier studies, this research emphasizes the importance of both identification and stabilization of key process parameters in a dynamic mining environment. The integration of these tools aims to offer a replicable framework for quality and efficiency improvement in other industries facing similar challenges.

2. Method

In analyzing the cycle time in the coal mining process, the use of quality tools is carried out with a systematic approach to identify, measure, and improve inefficient processes. There are seven tools that are particularly in the TQM effort, namely flowchart, check sheet, pareto chart, fishbone chart, statistical process control chart, histogram, dan scatter diagram (Heizer, Render and Munson, 2023). This research used only the first-five tools as the research method as depicted on Figure 1 below.

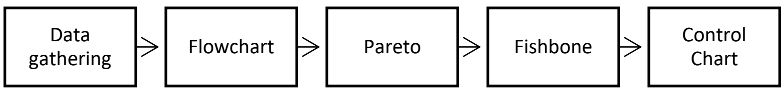

Figure 1. The quality tools

The first methos is flowchart. Flowchart is a simple tool but great in mapping all operational stages from excavation, transportation, storage in stockpile, quality inspection, to delivery to ships or customers. Flowchart is an excellent tool to understand and then try to improve the business process (Han and Trimi, 2018; Jayashree *et al.*, 2021). By visualizing these flows, companies can easily see critical points that are prone to delays or disruptions. Second is check sheet. This research used this tool because check sheets help analysts discover facts or patterns that can assist the analyst in controlling the quality of the process (Maheswari *et al.*, 2020). Daily data in this research is collected using a check sheet, which records the cycle time of each heavy equipment, weather conditions, and potential technical or logistical obstacles that occur during the process. After the data is collected, the analysis is continued using the third method, i.e. pareto chart. This method is used to identify the dominant factors causing the cycle time delay (Kursunoglu, 2023) . If it is found that, for example, 80% of delays are caused by 20% of machine damage or muddy roads, then the focus of repairs can be directed to those areas. The fourth method is fish-bone chart. It is a schematic technique used to discover the root cause of quality problems

(Maheswari *et al.*, 2022). Antony et al. (2023) stated that 95% of problems in processes can be solved using the 7 QC tools. To monitor the stability of the process over time, a control chart (the fifth method) is used that shows whether the cycle time is still within acceptable variation limits. The control chart functions by setting Upper Control Limit (UCL) and Lower Control Limit (LCL) based on statistical parameters, namely the average (mean) and standard deviation of the observed data (Jacobs and Chase, 2021). These control limits help to determine whether any observed variations are due to common causes or special causes that require corrective action (Harwani and Maheswari, 2015). The seven tools TQM is recommended for all business because the cause of defects can be identified early (Sutrisno, 2022).

This research uses the control chart to analysis whether the cycle time in coal mining process is meeting design specification and to detect the next process may not meet specifications. This research used $\bar{X}\ chart,$ a quality characteristic that are measured in actual weight, volume, duration or time and other measures. If there are repeated deviations found on the control chart, then fishbone diagrams are used to dig up the root cause based on human, machine, method, material, and environmental factors. By combining all these tools in an integrated manner, companies can implement a continuous improvement cycle based on concrete and measurable data.

3. Results and Discussion

3.1 Coal Mining Process Mapping Using Flowchart and Check Sheet

The coal mining process is a complex series of activities that involve many stages from excavation to delivery to consumer. Therefore, to understand the workflow thoroughly, it is necessary to map the process using *flowcharts* (see Figure 2). Flowcharts provide a systematic visual overview of how each activity relates to each other and where potential problems may arise. That way, companies can more easily identify critical points that can affect the *cycle time* or cycle time of coal production.

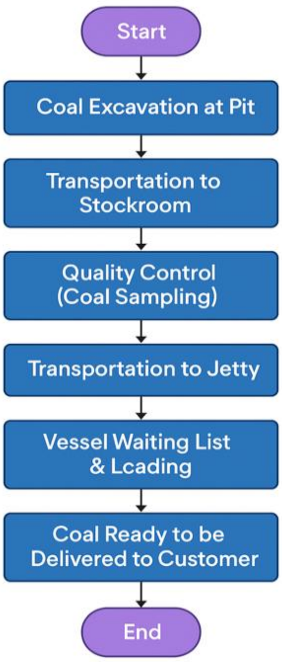

Figure 2. Flowchart

The first stage in the flowchart is the excavation of coal in the pit area using a PC 300 excavator. This is where the physical process of exploration begins, where operators operate heavy equipment to dig up coal seams from ground level. Speed and accuracy at this stage are crucial because incorrect excavation size or tool delays will have a direct impact on the timing of the next cycle. After excavation, the coal is transported by dump truck to the stockroom as an initial storage place. This haulage process includes route planning, truck fleet management, and monitoring of hauling road conditions(Maharani, Hermana and Yuniarto, 2022). Travel time and utilization of dump trucks are important parameters recorded in the check sheet to monitor transportation efficiency. From the stockroom, the coal is moved to the stockpile, which is the main storage location before being distributed. This is where the daily production batch is centered to facilitate delivery coordination. Stockpile arrangements must pay attention to stack capacity and heavy equipment access, so that there are no queues or build-ups that hinder the next process. At the stockpile point, sampling is carried out for Quality Control (QC). This sampling procedure ensures calorie content and other parameters as per the market specifications. The initial QC results determine whether the coal batch can be directly processed further or needs adjustments—e.g. mixing with other batches—before shipment. Next, the coal is transported to the jetty (delivery dock), where further QC sampling is carried out before the loading process to the ship. This second sampling ensures that the quality of coal remains consistent after handling it in the field. If it passes the QC, the operator will start the loading process: loading and unloading from the truck to the ship via a conveyor or grab crane. After the loading process is completed, the coal is ready to be sent to customers, especially coal-fired power plants and the industrial sector in Lampung.

With a structured Figure 2, each stage is clearly in order, minimizing the risk of overlapping tasks or queues. This helps management monitor cycle time, identify potential bottlenecks, and take corrective actions quickly. By combining flowcharts and check sheets, companies get a combination of macro images (process flows) and micro data (time records and daily interruptions). Flowcharts help management and engineers to see the entire operational structure, while check sheets are a tool to monitor and measure the performance of each stage in the process. This approach is also important in an effort to improve the process through the continuous improvement method. The application of check sheets is not only used to record the time, but also to classify the types of disturbances that occur most frequently. For example, companies can distinguish whether an obstacle occurs due to rain, damaged roads, heavy equipment damage, or ship queues. With this classification, the operational team can create a Pareto analysis that will show which factors are most dominant in causing *cycle time* delays. This process mapping also supports data-driven decision-making (Simatupang, Barasa and Kusuma, 2019). Management no longer relies on assumptions or conjectures, but on evidence obtained from check sheets and flowchart analysis results. If a recurring obstacle is found at a certain point, then the improvement can be immediately focused on that point. This cannot be done if you conduct a performance analysis on a product that has been completed (Aboelmagd, 2018), let alone only by calculating business productivity (Rafi and Witjaksana, 2023). For example, if the ship loading queue is the main obstacle, then the management can design a more efficient loading schedule or add loading facilities. The use of flowcharts and check sheets in mapping the coal mining process is an important foundation in effective operational management. These two tools not only help understand processes and problems but also serve as a solid foundation for the development of sustainable production efficiency strategies. By consistently applying this approach, companies can increase productivity, reduce operational costs, and maintain the quality of the coal produced.

3.2 Identify and Analyze the Causes of Cycle Time Inefficiency

In coal mining operational activities, cycle time is an important indicator that reflects production efficiency. When cycle time experiences delays or inefficiencies, it will have a direct impact on daily output, production costs, and the reliability of distribution to consumers. To address this, companies need to identify the root causes of these inefficiencies using a structured and data-driven quality tools approach. One of the most effective quality tools in the identification stage is Pareto Chart Figure 3. This diagram is based on the 80/20 principle, which is that about 80% of problems come from 20% of the main causes. By processing data from daily check sheets that record disruptions during the mining process, companies can find out which types of disruptions are most frequent and have a major impact on cycle times. For example, if the data shows that outages are most often caused by rain, loading queues, and equipment malfunctions, then these three factors need to be prioritized for further analysis.

The coal mining process begins with coal mining in the pit area using heavy equipment such as the PC 300 excavator. This stage is a crucial starting point because the quantity and quality of coal excavated will affect the smooth running of the next process. The proper and efficient use of heavy equipment is essential to ensure that coal can be extracted optimally and reduce downtime that can occur due to tool damage or negligence in its operation. After the coal is dug up, the coal is transported using a dump truck to the stockroom. The stockroom serves as a temporary storage place before the coal is moved to the stockpile. At this stage, it is important to monitor transportation times, as well as manage travel routes and dump truck fleets effectively so that there are no congestion or vehicle build-ups that hinder the workflow. The coal is then moved to the stockpile, which is the main storage location used to hold the coal before it is further distributed (Rifky, 2019; Maheswari *et al.*, 2022; Cipta *et al.*, 2025). In this stockpile, coal is sorted and arranged according to the quality and needs of the market. Good stockpile safety and management will minimize damage to the coal and smooth the subsequent transport process to the jetty. At the stockpile point, sampling is carried out for Quality Control (QC). This QC aims to ensure that the stored coal meets quality standards, particularly related to calorie content that matches market demand. Sampling is carried out to ensure that the quality of coal does not undergo adverse changes during the storage and transportation process. After passing the QC in the stockpile, the coal is then transported to the jetty or shipping dock, where the coal is loaded onto the ship for further distribution.

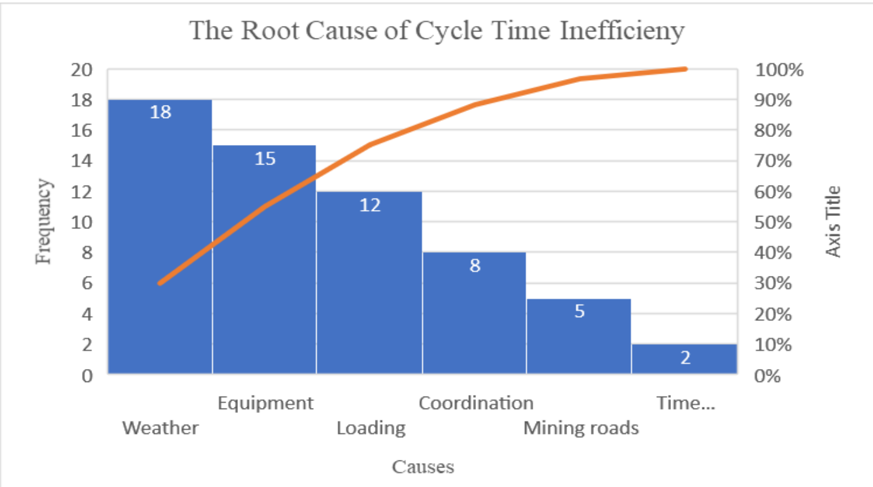

Figure 3. Pareto chart

At this jetty, the coal is again inspected through advanced QC sampling before being transferred to the ship. This process ensures that the coal that arrives at the customer is of the quality that is promised, especially in terms of calorie content and material purity. After passing a rigorous QC testing process, the coal is ready to be loaded onto the ship and shipped to the customer. This shipment covers the industrial sector and coal-fired power plants in the Lampung area. A well-structured flow from digging to delivery ensures that every stage is executed efficiently, reducing potential delays, and maintaining the quality of coal that reaches the end consumer. The types of defects (defects/constraints) and the number of events that can be used in analysis such as check sheets and pareto charts in the context of cycle time optimization in the coal mining process in Table 1.

Once the dominant cause has been identified, the next stage is the root of the problem analysis using the Fishbone /Cause and Effect/Ishikawa Diagram (Figure 4). This diagram helps to break down the causes of inefficiencies based on categories such as Man (HR), Machine (heavy equipment), Method (work method), Material, Environment (weather/location), and Measurement. For example, delays due to rain can be analyzed more deeply in terms of the environment and working methods, while equipment damage can be linked to suboptimal maintenance (man and machine).

Table 1: Types of defects

No.	Type of Defect/Obstacle	Number of Events	Present (%)
1	Extreme Weather (Heavy Rain)	18	30%
2	Heavy Equipment Damage	15	25%
3	Loading queue at jetty	12	20%
4	Delays in coordination between teams	8	13.3%
5	Damaged/slippery mining roads	5	8.3%
6	Errors in time measurement	2	3.4%
	Total	60	100%

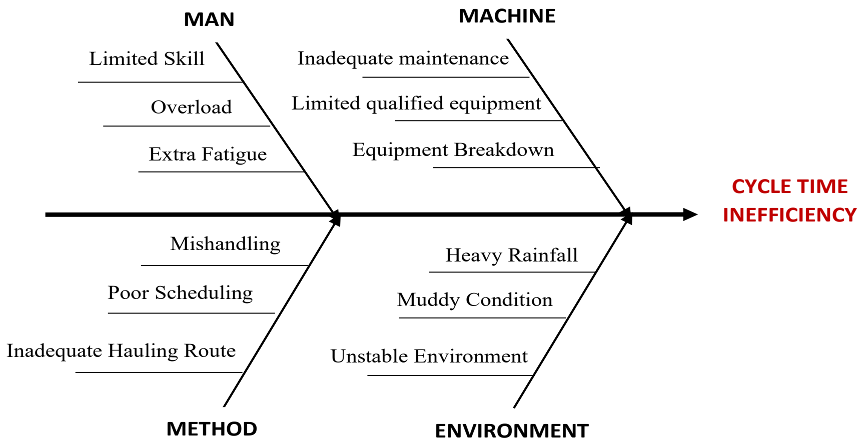

Figure 4. Fishbone diagram

The Fishbone Diagram above (see Figure 4) maps the various factors that cause the main inefficiency in cycle time in the mining process. In the "Man" section, limited operator skills, overload, and operator fatigue can contribute to the slowdown of the work cycle. From the "Machine" side, the main factor is equipment breakdowns which can occur if the maintenance schedule is not set properly. When a breakdown occurs, the machine's downtime increases dramatically, so the idle time between processes expands. This combination of human resource shortages and weaknesses of the equipment or machine is the initial foundation for inefficiency. Meanwhile, in the "Method" branch, there are many mishandling works, poor scheduling of equipment, and inadequate hauling routes. The poor scheduling of equipment usage causes some units of heavy equipment to not optimize their capacity, for example dump trucks that wait too long for excavators or vice versa. The "Method" branch highlights that inefficient hauling routes and poor scheduling add to the length of the distance and cycle time such found in a research conducted by Kursunoglo (2023). If the haul road route is designed without considering the contour of the land or the condition of the pavement, then the operational vehicle must take a detour or pass through a more difficult path, so that the average speed of the vehicle decreases. Thus, planning work methods and scheduling are key to significantly shortening cycle time. "Environment" factors such as heavy rainfall, muddy conditions, and unstable environment affect the performance of heavy equipment and the speed of transportation. Heavy rain makes pit road surfaces slippery and muddy, so vehicle traction decreases, the risk of accidents or component damage increases, and operators are forced to drive at lower speeds. The interaction between extreme environmental conditions and technical constraints cumulatively extends the cycle time. To overcome this, mitigation measures are needed such as drainage improvements, routine maintenance, operator retraining, and a reliable monitoring system.

The application of these quality tools does not stop at identification but also becomes the foundation for making improvement decisions. By knowing the root cause, companies can develop targeted handling strategies, such as improving equipment maintenance systems, retraining operators, or adjusting production schedules to weather conditions. This is much more effective than simply adding a machine without knowing the root of the problem. One of the clear examples of the results of this analysis is the carryover policy or the addition of working hours during the dry season as a form of compensation for lost time in the rainy season. This policy arises not from mere conjecture, but from the results of consistent observation and analysis of operational data. Thus, the strategies taken are truly responsive and based on real field conditions (Han and Trimi, 2018). Through this identification and analysis process, the company demonstrates its commitment to a data-driven management approach in improving operational efficiency. The use of quality tools not only helps solve current problems, but also encourages a more systematic and scalable work culture in the future (Sutrisno, 2022; Antony, McDermott and Sony, 2023). This is an important step in increasing the competitiveness of mining companies, especially in the face of pressure on efficiency and stability of energy supply amid climate change and global markets.

3.3 Control and Improvement of Production Process Through Control Chart and PDCA Approach

Control of the production process in the coal mining industry requires a systematic approach to ensure that the quality and quantity of the products produced are always in accordance with the set standards. One of the tools that is effectively used to control this process is the control chart. Control charts allow companies to monitor process variability in real-time and identify whether a process is within control limits or experiencing variations that require corrective action (Jacobs and Chase, 2021; Heizer, Render and Munson, 2023). By using Control Charts, companies can detect problems early (Sutrisno, 2022), so that they can avoid the occurrence of larger product losses or mismatches.Observations were conducted in 20 operational days. The average delay is 160 minutes with a standard deviation of 12 minutes. The control limits are calculated as follows:

UCL = Mean + 3 × Standard Deviation = 160 + 3(12) = 196 minutes

LCL = Mean − 3 × Standard Deviation = 160 − 3(12) = 124 minutes

With these boundaries, any data point outside the 124–196 minutes range indicates a special cause variation, such as unexpected equipment breakdown or extreme weather delays. Figure 5 shows the control chart for daily cycle time, used to monitor whether the process is statistically in control or affected by special variations. Control Charts work by mapping the data obtained from the production process and identifying existing fluctuations. The data collected, e.g. cycle time, coal calorie content, or daily production amount, is mapped on a graph showing the upper and lower control limits. If the resulting value is outside the limits of this control, it means that there are discrepancies in the production process that must be addressed.

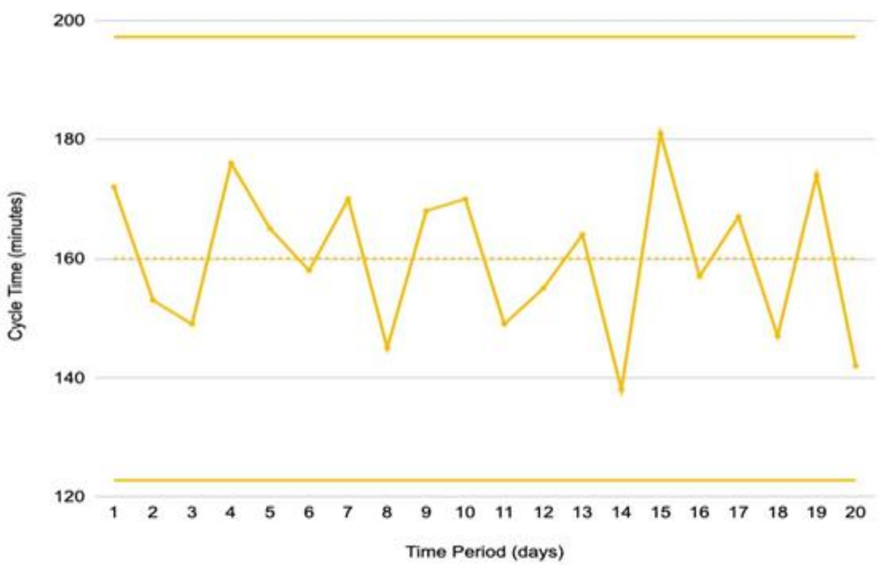

Figure 5. Control chart for cycle time

For example, if the calorie content of coal is not in accordance with the set standards, then the company can immediately adjust in the coal mining or processing process. This Control Chart is created to monitor the stability of daily cycle time for 20 operational days. By plotting the value daily, management can see how consistent the turnaround time of a single mining cycle—from digging to ready coal for transport. The goal is to ensure that the process is within the control limits that have been set, so that only natural variations occur, not significant deviations. The dotted line in the middle of the graph indicates the mean of the overall data cycle time. Meanwhile, the upper (UCL = mean + 3σ) and lower (LCL = mean – 3σ) dotted lines describe the three sigma control limits. This limit was chosen because it covers almost 99.7% of the variation expected if the process is truly stable, so only extreme fluctuations will exceed that limit. Any data point that falls within the UCL and LCL lines indicates that the process is running normally and that the variation is still acceptable. However, if there is a point that passes through the UCL or LCL—or a special pattern appears (e.g., several points in a row near the limit)—then this indicates a potential problem such as equipment malfunction, extreme weather conditions, or procedural errors. These points should be investigated immediately to find the root cause. The results of this monitoring then become inputs in the PDCA (Plan-Do-Check-Act) cycle. After detecting anomalies, the team drew up a plan to address the cause of the deviation, implement improvements (Do), re-check post-fix data on the chart (Check), and follow up on the evaluation results (Act). Thus, Control Charts not only monitor, but also encourage continuous improvement to lower cycle time and improve operational efficiency as explained by Maharani (2022) dan Sutrisno (2022). To ensure that process control is effective, companies need to combine the use of Control Charts with the PDCA (Plan-Do-Check-Act) approach.

PDCA is a continuous improvement cycle that assists companies in planning changes, implementing those changes, evaluating the results, and then making further improvements based on those evaluations. In the context of production control, PDCA can be used to address problems detected through Control Charts, as well as to ensure that corrective actions taken provide optimal results. The first stage in the PDCA cycle is the Plan, where the company identifies areas that need improvement. For example, if the Control Chart shows significant fluctuations in the calorie content of coal, this planning stage will include an analysis of the causes of the variation and the formulation of the steps that need to be taken to address it. This could involve revisions in quarrying, coal removal, or coal processing techniques in the stockpile to improve product quality consistency. The next stage is Do (Implementation), where the planned steps are implemented. In this case, companies can implement changes in the production process, for example by updating standard operating procedures (SOPs) or training operators to avoid errors that could lead to quality variations. The implementation of these changes needs to be done carefully so that the process continues without disrupting the existing production flow. After the Do stage, the company needs to conduct a Check stage to evaluate whether the changes implemented have yielded the desired results. At this stage, the data that has been collected post-change will be compared with the previous data recorded on the Control Chart. If the results show that the variation in quality or cycle time has decreased and is within acceptable control limits, then it can be considered that the changes made are effective. The final stage of the PDCA cycle is the Act, where the company determines whether the changes implemented should be maintained or further refined. If the results of the audit show that the improvements made do not have a significant impact, the company should return to the planning stage and make adjustments. Conversely, if the results are satisfactory, the company will proceed with standardizing the changes and ensuring that the new procedures become part of daily operational practices.

By combining Control Chart and PDCA, the company can continuously monitor and improve its production processes (Maheswari *et al.*, 2022). This not only helps control variability in product quality, but also allows companies to respond to changes in production conditions or problems that arise more quickly and effectively (Antony, McDermott and Sony, 2023). This approach ensures that companies can maintain production efficiency, reduce waste, and improve customer satisfaction through consistent, quality products.

3.4 Evaluation of the Coal Production Process Flow

Evaluating the flow of the coal production process is an important step in understanding the entire operational stages from upstream to downstream. This process starts from the coal digging stage in the pit, where mining activities are carried out using heavy equipment such as excavators and dump trucks. Efficiency at this stage is highly dependent on field conditions, operator skills, and machine readiness. Obstacles such as heavy rain or machine failure can slow down the excavation rate and have a direct impact on delays in the next process. After the coal is dug up, the next stage is transportation to the stockroom. At this stage, the coal that has been collected in the pit is transported to a temporary shelter for further processing. Transportation routes that are not optimal or muddy road conditions due to bad weather can cause long cycle times. Therefore, monitoring the condition of the hauling line and effective truck scheduling are important factors to maintain time and cost efficiency. The coal quality control or sampling stage is carried out in the stockroom to ensure the quality of the coal is in accordance with the specifications set by the customer. This process includes representative sampling, testing of moisture content, ash content, and calorific value. Accuracy in the sampling process is very important because the results will affect consumer confidence and the smooth sales process. Delays or errors in quality control can have an impact on delivery delays. After passing the quality control, the coal is then transported to the jetty or port as the next stage. This transportation must be managed efficiently to avoid bottlenecks, especially when truck queues or bad weather hinder the moving process. The availability of transport vehicles and coordination between field teams and ports are crucial so that coal flows smoothly.

Arriving at the jetty, the coal enters the waiting list stage of the ship and the loading process. This is a critical stage that is heavily influenced by the readiness of the marine fleet and the efficiency of loading and unloading. If the ship is not available or there is a delay in loading, then the coal already in the port will accumulate, adding to the cost and risk of degradation. Therefore, synergy between the logistics team and the shipping party is urgently needed in this process. After the loading process is completed, the coal will be ready to be delivered to consumers according to the contract and delivery schedule. At this point, the entire coal production and distribution process reaches its final stage. However, it is important to note that any delays or errors in the earlier stages will have a direct impact on the accuracy of delivery and customer satisfaction. Therefore, a thorough evaluation and monitoring of each stage in real time is very necessary. Of the entire coal production process flow, there are several crucial points that greatly affect efficiency, namely: the readiness of heavy equipment in the pit, the condition of the hauling road, the accuracy of quality sampling, the availability of trucks and ships, and the reliability of the interdepartmental coordination system. Failure at just one point can cause a domino effect that hinders the entire process. Therefore, it is important to conduct regular evaluations and identify potential improvements systematically. The evaluation of the coal production process flow aims to find gaps in problems that can be corrected so that cycle time can be reduced (Kamari and Madelan, 2020), coal quality is maintained, and consumer satisfaction can be improved. Data-driven approaches, such as the use of control charts and PDCA methods, can be a very effective tool in maintaining consistency and improving operational performance.

4. Conclusion

This research has proven the use of control chart in controlling cycle time of coal mining process is a very effective tool to monitor the stability and consistency of the production process as found also by Ehrlinger & Wöß, (2022). Data visualization through control graphs allows management to detect abnormal variations that can affect efficiency early. Control limits calculated from mean values and standard deviations provide objective indicators of operational performance, so that any significant deviations can be investigated and acted upon immediately (Gackowiec *et al.*, 2020). In addition to being a monitoring tool, Control Charts also play an important role in supporting a continuous improvement approach through the Plan-Do-Check-Act (PDCA) cycle. Any deviation that arises triggers evaluation and updates to work procedures, workforce training, or equipment improvements. By keeping the cycle time within control, companies can maintain production quality, operational efficiency, and product delivery accuracy (Zacharias, 2022).

However, this study still has several limitations, such as the limited time frame of data collection which only covers 20 operational days, and external factors like seasonal shifts or management policy changes that are not fully observed in this study. Practically, the use of quality tools in this study can assist companies in identifying bottlenecks and developing improvement strategies that are structured and measurable. The PDCA cycle offers a practical framework that can be adapted across different operational areas. From a scientific standpoint, this research contributes to the development of quality management in the mining industry by integrating classical quality tools with control charts to manage cycle time. This approach can serve as a reference for similar industries that aim to achieve stable and efficient operations through data-driven decisions.

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