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Optimizing Coal Production Estimates: Balancing Topographic Surveys Method and Truck Counts Method at Pit Kress, PT. Bordun Indie, South Kalimantan, Indonesia

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ABSTRACT
Accurate coal production estimation is essential to support efficient decision-making and operational success in the mining industry. Discrepancies between estimation methods, such as truck counts and topographic surveys, often lead to inefficiencies and failure to achieve production targets. This research aims to identify the root causes of such discrepancies at PT Bordun Indie and propose effective solutions to improve the accuracy of production estimation. Using the DMAIC (Define, Measure, Analyze, Improve, Control) methodology, this research analyzes critical factors such as human error, absence of standard operating procedures (SOPs), and reliance on manual data entry. Descriptive statistical approach and linear regression analysis were used to measure the variation and relationship between the two estimation methods. The results showed that the implementation of process standardization, digital technology integration, and continuous monitoring significantly reduced data variability, thereby improving the accuracy of production estimation. The implications of this research are not only relevant for PT Bordun Indie, but can also be widely applied in the mining industry to optimize production planning, improve decision-making, and support better achievement of production targets. This research confirms the importance of systematic improvement to drive operational efficiency and sustainability in the mining sector.

Keywords: Coal Production, Deviation, DMAIC Framework, Truck Counts Method, Topographic Survey Method.

INTRODUCTION

The coal mining industry is a vital sector supporting the global economy (Fitriyanti, 2016), including in Indonesia. PT. Bordun Indie, as one of the leading mining companies, has set an ambitious target to increase coal production from 46.8 million tons in 2024 to 54 million tons the following year. To achieve this target, careful planning and effective operational strategies are needed. One of the crucial elements of good mine planning is the availability of accurate and reliable production data, which is used for performance evaluation, planning, and data-driven decision-making (Shaddad et al., 2024).

The two main methods used to measure coal production are truck count estimation and topographic surveys (Prasmono, 2015). Estimating the number of trucks involves calculating the amount of material transported based on the number of truck trips from PIT Kress to ROM stockpile. Although this method is often used due to its convenience and relatively low cost, it has a drawback in terms of accuracy. In contrast, topographic surveys use well-calibrated measuring tools such as Total Station and Real Time Kinematic, resulting in more accurate data on the volume of material in the field. However, based on production data from 2020 to July 2024, it was found that the data from the truck counting method was highly volatile, with deviations that often exceeded the accepted tolerance limit of less than 5%.

Descriptive statistics are used to analyze the variance of the measurement results of each method by calculating descriptive measures such as variance and standard deviation (Vivi Silvia, 2020). These steps help identify data fluctuations and determine methods with greater variance as objects of further research. The expected result is that the variance in the estimated number of trucks is close to the variance of the topographic survey results, indicating that the fluctuations in both methods are relatively similar.

In addition, linear regression analysis was applied to evaluate the relationship between the measurement methods (Maulud & Abdulazeez, 2020). The estimate of the truck counts is used as a dependent variable (Y), while the results of the topographic survey method as an independent variable (X). The purpose of this analysis is to ascertain the linear relationship between the two methods and to measure how well the survey results can explain the variation in the truck counts method. An expected R-square value of more than 0.95 indicates that topographic surveys can account for more than 95% of the variation in the truck counts. This high R-squared value is important because it ensures that linear regression models are highly accurate in explaining the relationship between the two methods, which has an impact on the reliability of coal production estimates and decision-making in companies.

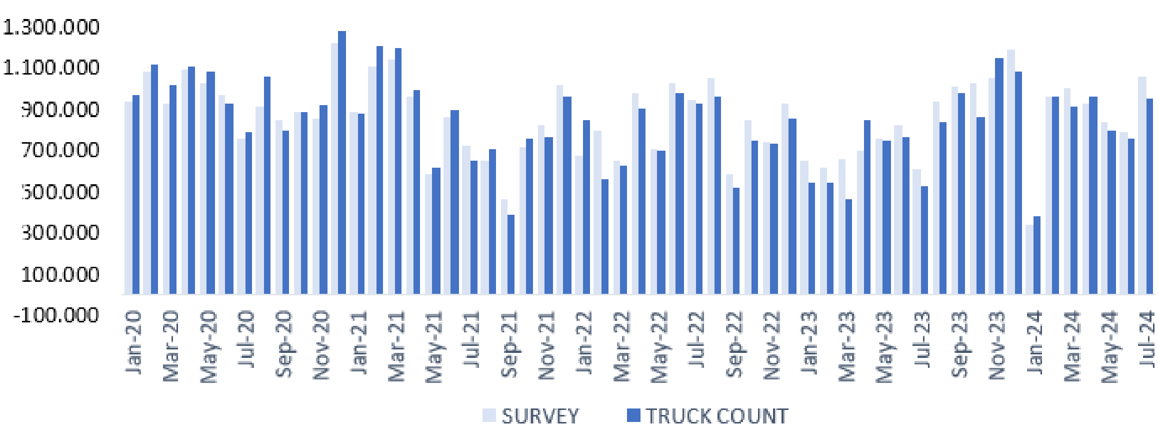

Figure 1. Coal production from January 2020 to July 2024

The inaccuracy of production data generated by the truck counts method can be caused by a variety of factors, including truck capacity variability, inaccuracies in the weighing process, and human error (Bepswa, 2016). Meanwhile, data from topographic surveys that tend to be more stable and accurate show more consistent results. Therefore, this research aims to evaluate the fluctuations between the truck counts and topographic surveys in coal production measurements, as well as identify strategies to correct the causes of significant deviations. By maintaining deviations within the accepted tolerance limits, it is hoped that production planning can be more optimal, thereby supporting the achievement of higher production targets in the future.

In conducting this research, it was found that similar research had been conducted on overburden, whereas this research specifically focused on the discrepancy between the truck counts and topographic surveys in estimating coal production. Based on research conducted by (Kurnia et al., 2015), it is known that the cause of the difference between the truck counts method and the topographic survey of the volume of the removed overburden occurs due to the use of inaccurate constants, the neglect of equipment filling factors, the assumption of uniform truck loads, and unideal operating conditions such as sludge materials that reduce carrying capacity.

Based on the above background, the objective of this research is to evaluate the difference between production estimation methods using truck counts and topographic surveys, and identify the factors that cause significant discrepancies in results. This research also aims to formulate improvement strategies that can increase the accuracy of coal production estimation and keep the measurement results within acceptable tolerance limits. The benefits of this research are to provide solutions that can be implemented to reduce the variability of production estimation data, improve mine planning efficiency, and support the achievement of higher production targets. In addition, this research is expected to be a reference in improving the reliability of production measurements in the mining industry in general, as well as encouraging more optimal use of technology and standard procedures to support data-based decision making.

RESEARCH METHOD

This research adopts a mixed-methods approach, integrating both quantitative and qualitative data to thoroughly analyze the deviations in coal production estimates between the truck count method and the topographic survey method. The DMAIC (Define, Measure, Analyze, Improve, Control) framework from Six Sigma is utilized to enhance estimation accuracy and reduce discrepancies between these two methods (Lemke & Strulak-Wójcikiewicz, 2021). The detailed steps are outlined below.

1) Define: In this phase, the problem was identified as the inconsistency in coal production estimates when comparing the truck count data with topographic survey data. The objective is to pinpoint the primary causes of this deviation and set clear goals for improvement.

2) Measure: During the measurement phase, data was collected using both qualitative and quantitative methods to capture a holistic view of the factors contributing to estimation discrepancies.
   a. Qualitative Methods: Interviews with key stakeholders, observations of the data collection process, and discussions helped to identify procedural gaps and potential sources of human error, such as the lack of standard operating procedures (SOPs).
   b. Quantitative Methods: Historical data, including demurrage, truck count, and summary volume, was gathered. Specific measurements included density sampling and truck count sampling, along with accuracy tests and calibration processes. These quantitative measures were essential for evaluating variations between the methods and ensuring data precision.
3) Analyze: In the analysis phase, both descriptive statistics and linear regression analysis were employed to investigate the relationship and variation between truck count data and topographic survey data.
   a. Descriptive Statistics: This analysis was chosen to summarize the data and provide a clear view of variability and central tendencies, which allowed for identifying patterns and anomalies in the data.
   b. Linear Regression Analysis: Linear regression was used to examine the correlation between truck count data and topographic measurements, allowing for a deeper understanding of the consistency between these methods. This method was selected due to its ability to predict outcomes based on existing variables, providing insights into the reliability of the truck count method as an estimator.
4) Improve: Based on the findings from the analysis, specific improvement strategies were implemented. These included the standardization of processes, the integration of digital technologies to reduce manual entry errors, and the development of SOPs to ensure consistency in data collection.
5) Control: Finally, a control phase was established to maintain the improvements achieved. Continuous monitoring and periodic reviews were set up to ensure ongoing accuracy in production estimation and prevent future deviations.

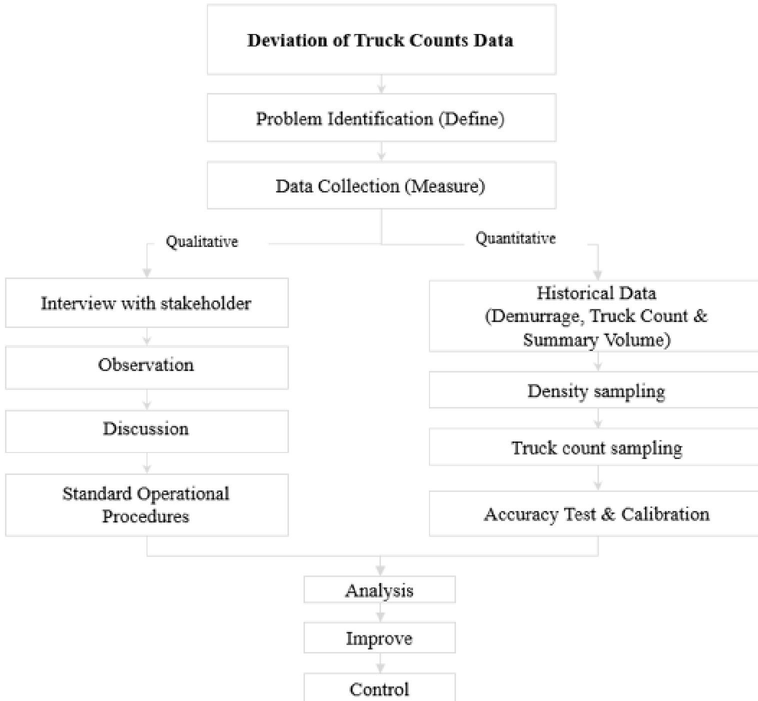

Figure 2. Research Design

RESULT AND DISCUSSION

Define

This research started from the main problem, namely the fluctuating deviation greater than 5% and smaller than -5% between the estimated coal production using the truck count method and the results of topographic survey measurements at the Pit Kress PT. Bordun Indie during 2020 to July 2024. Such deviations have a significant impact on the accuracy of production reporting and have the potential to cause financial losses for the company, including errors in sales planning that can result in additional costs such as demurrage. Therefore, the project aims to reduce the deviation between the two measurement methods to less than ±5%.

Customer needs are identified through a Voice of the Customer (VOC) approach, where data users express the need for a more accurate and efficient reporting system (Freeman & Radziwill, 2018). Production teams need reliable estimates to support operations, while marketing requires the right data for marketing and shipping planning (Rao, 2023). The management also hopes that the difference between daily production data based on truck count and survey results will be minimal to ensure production accuracy and prevent sales planning errors.

The scope of activities includes collecting data from the Pit to ROM Stockpile, topographic survey measurements, and data recording in the Pit Kress, with the exception of activities outside the pit, such as measurements in other areas or the use of Weigh in Motion (WIM).

A process map (SIPOC) is created to understand the overall process flow, which identifies suppliers, inputs, processes, outputs, and customers of the existing system.

Table 1. SIPOC of the Production Reporting Process

Supplier	Input	Process	Output	Customer
Hauler's Operator	Trip information, time sheet form	Report information via radio, manual report collection	Trip report	Dispatcher
Dispatcher	Truck count data from operator hauler	Entering and sending data in Excel format to Operation Control Centre Engineer	Dispatch report	Operation Control Centre (OCC)
Operation Control Centre (OCC)	Dispatch report	Data verification & reconciliation	Production report	Reporting officer
Reporting Officer	OCC Report	Input into daily production report format	Daily production report	Production Supervisor, Mine Plan Engineer, Geologist, ROM and Hauling Supervisor, Marketing, Management
Topographic Surveyor	Raw data	Data validation and processing	Summary volume report	Reporting, Officer, Production Supervisor, Mine Plan Engineer, Geologist, ROM and Hauling Supervisor, Marketing, Management

Data collection and production reporting begins with the Hauler Operator, who reports trip information via radio, which is then manually recorded. The Dispatcher enters this trip data into an Excel format and sends it to the Operation Control Centre (OCC) for verification and reconciliation, resulting in a Production Report. The Reporting Officer processes this report into a daily production report used by various stakeholders, including the Production Supervisor, Mine Plan Engineer, Geologist, ROM and Hauling Supervisor, Marketing, and Management. Meanwhile, the Topographic Surveyor validates and processes raw data to produce coal volume and tonnage information utilized by the Operation, Finance, Geologist, and Management divisions, ensuring that the process runs accurately and supports efficient decision-making.

Measure

In the Measure stage in this research, the main focus is to collect quantitative and qualitative data needed to understand the cause of the deviation between the estimated coal production using the truck count method and topographic survey measurements in the Pit Kress of PT. Bordun Indie. Quantitative data is collected from various secondary and primary sources, such as daily production reports that record truck count data (January 2020 to July 2024 period), volume summary reports (January 2020 to July 2024 period), and truck count sampling data for each hauler unit. To measure the density of coal, density test data is obtained from drilling results (secondary data) and grab sampling (primary data), while the accuracy of measuring instruments such as total station (TS) and Real Time Kinematic (RTK) is tested through the collection of primary data to ensure the accuracy of the survey results.

In addition to quantitative data, qualitative data is also collected through SOP Sampling truck count analysis as secondary data to understand the operational standards applied. Direct observation of the process of recording and reporting truck count data is carried out to identify potential errors in recording in the field. Discussions with relevant stakeholders, including operators, dispatchers, surveyors, and management, are conducted to gain insight into operational challenges and the factors that affect data accuracy. This Measure stage provides a strong foundation for analyzing the root cause of deviation by combining quantitative and qualitative data, which will then be used for improvement at the Analyze and Improve stage (Nurazizi, 2023).

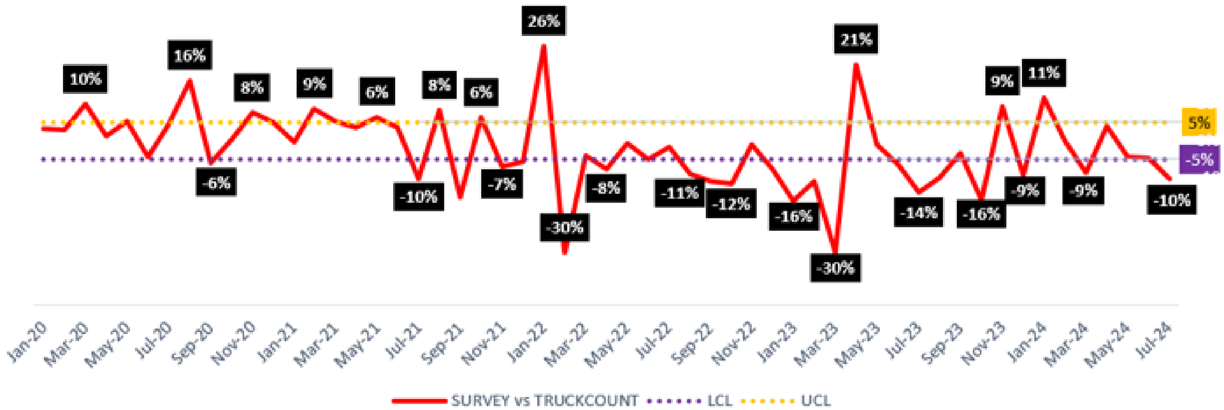

Figure 3. Monthly Deviation

The graph above (Figure 3) illustrates the monthly deviation between the estimated coal production using the truck count method and the results of the topographic survey at the Pit Kress of PT. Bordun Indie from January 2020 to July 2024, with the red line showing the difference between the two measurement methods and the dotted line as the upper and lower control limits (UCL) and lower (LCL) at ±5%. Significant fluctuations in the graph, with peak deviations reaching -30% and 26%, indicate high instability and variability in the measurement process

Descriptive statistical analysis (Table 2) shows that the average production estimated by the truck calculation method is 842,423 tons, while by the survey method, it reaches 859,382 tons. The high variance in the truck count method of 42,897,405,529 compared to the survey method of 34,725,365,544 indicates a greater fluctuation in truck data recording. This significant standard deviation indicates the data instability of the truck counting method.

Table 2. Descriptive Analysis

	Truck Count	Survey
Mean	842,423	859,382
Standard Error	27,928	25,127
Median	858,447	884,543
Standard Deviation	207,117	186,347
Sample Variance	42,897,405,529	34,725,365,544
Kurtosis	-0.24	-0.05
Skewness	-0.27	-0.42
Range	900,391	879,331
Minimum	376,539	337,926
Maximum	1,276,930	1,217,257
Sum	46,333,240	47,265,983
Count	55	55

Linear regression is used to analyze the linear relationship between topographic surveys (independent variables) and truck counts (dependent variables) to evaluate the reliability of truck count estimates. This method measures how much variation in truck counts is explained by the survey, indicated by the R^2 value indicating the strength of the relationship, and allows prediction and identification of deviations for process improvement.

The scatter plot graph (Figure 4) shows an R^2 value of 0.8474, which means that 84.74% of the truck count variation is explained by the topographic survey, indicating a strong relationship between the two methods, but there is still 15.26% unexplained variation due to operational factors, procedural differences, or recording errors, so this analysis is essential for improving the recording process and improving the accuracy of estimation.

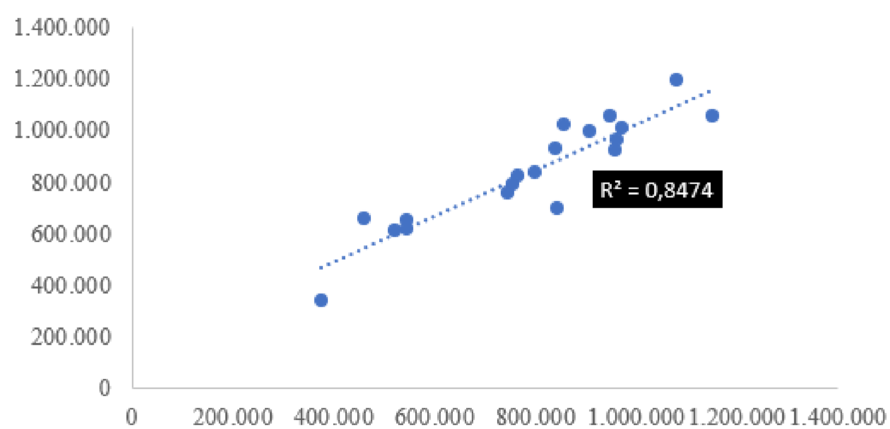

Figure 4. Scatter plot shows the linearity of truck counts and topographic survey

Based on the analysis of the measurement results, the comparison between the truck count method and the topographic survey in the Pit Kress of PT. Bordun Indie from January 2020 to July 2024 shows significant variability and instability in coal production estimates. The monthly deviation graph shows peak fluctuations reaching -30% and 26%, exceeding the acceptable control limit of ±5%, which indicates a high inconsistency in the truck count method. Descriptive statistical analysis showed a high variance in the truck count data of 42,897,405,529 compared to the survey of 34,725,365,544, showing the instability of the truck count method data. The scatter plot analysis showed an R^2 value of 0.8474, which means that 84.74% of the variation in the truck count estimate could be explained by the topographic survey, but 15.26% of the unexplained variation showed the influence of operational factors, procedural inconsistencies, and recording errors. The factors that affect this instability will be explained in more detail in the analysis stage.

The accuracy measurement for the two topographic survey instruments, Total Station and RTK, has been carried out by measuring 20 identical points with both instruments. Based on the scatter plot, an R2 value of 0.9917 was obtained. This means that the two measurement tools have a very strong linear relationship and very high accuracy. In other words, both instruments provide nearly identical and highly consistent results when measuring the same points.

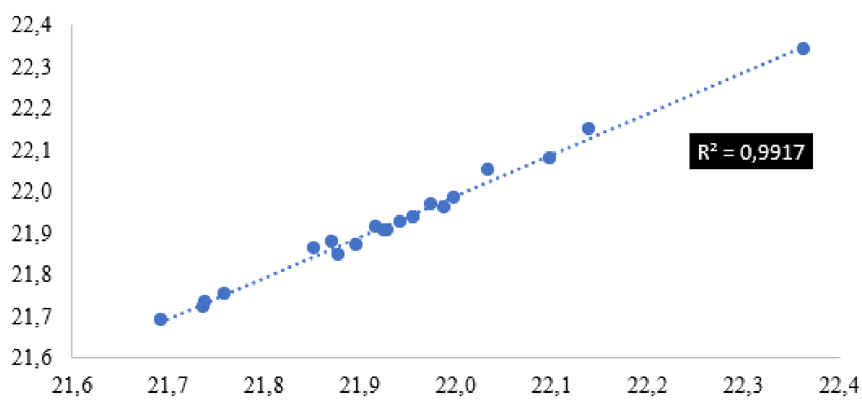

Figure 5. Scatter plot shows the linearity of both topographic measurement tools

Analysis

The analysis stage aims to identify the root cause of significant deviations that occur between the estimated coal production using the truck calculation method and the survey method. Based on the data collected at the measure stage, descriptive statistical analysis, linearity test, and Ishikawa chart analysis were carried out to understand the main factors that contributed to the deviation.

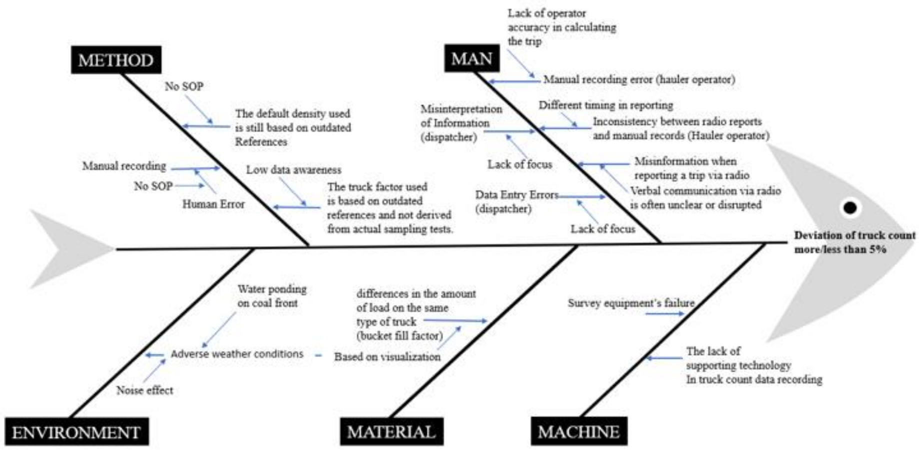

Figure 6. Root Cause Analysis (Ishikawa)

Ishikawa's diagram (Figure 6) illustrates the various potential causes of truck count deviations of more or less than 5%, which are grouped into five main categories: Methods, People, Materials, Machinery, and Environment (Juliandra, 2022).

In the human category, there are several significant operational errors, such as the operator's lack of accuracy in trip calculating, manual recording errors by hauler operators, and misinterpretation of information by dispatchers. Dispatchers often make mistakes in entering data due to unclear reporting via radio, inconsistencies between radio reports and manual records, and lack of focus in carrying out tasks (Dash, 2023).

In category of methods, key issues include the absence of Standard Operating Procedures (SOPs), reliance on manual recording, and low data awareness. The use of outdated references, such as default density and truck factors that are not derived from actual sampling tests, highlights critical gaps in data management and procedural standardization, leading to significant human errors.

In terms of materials, the difference in the amount of load on the same truck type is often based only on visualization and not on accurate measurements. This condition is exacerbated by the presence of puddles on the coal front, which can cause the survey team to fail to take data, so that the coal that has been taken from the area cannot be measured properly.

For the machinery category, the failure of survey equipment is the main cause, mainly due to lack of maintenance and obsolescence of the equipment. In addition, the lack of supporting technology in recording truck count data also magnifies the potential for errors because processes that still rely on manual recording are prone to errors.

Finally, in the environmental category, poor weather conditions play a major role in disrupting the visibility and accuracy of measurements. The effects of noise from the mine area can affect communication between hauler operators and dispatchers, increasing the likelihood of misinformation in reporting. Overall, the truck count deviation is caused by a combination of these factors, indicating the need for improvements in procedures, increased training, integration of more modern technologies, and handling of operational conditions to improve data accuracy and production efficiency.

Improve

The Improve stage focuses on the development and implementation of improvement solutions to address the root cause of deviations in the estimated coal production that have been identified in the analysis stage. Based on the results of the previous analysis, improvements are directed to errors in recording and reporting data caused by human factors and the absence of standard operating procedures (SOPs). The goal of this stage is to reduce data variability and ensure that the process of recording and reporting production data becomes more accurate and consistent.

1. Standardization of Recording and Reporting Procedures.
   The first step taken is to develop a clear and standardized SOP for the process of recording and reporting coal production data. This SOP is designed to ensure that all operators follow the same procedure when recording the number of truck trips and the volume of coal transported. The new procedures also include guidance for accurate data filling, data verification steps, and error reporting mechanisms that can be quickly identified and corrected. With this SOP, it is hoped that consistency and accuracy in data recording will increase.
2. Training
   The training includes several key aspects: first, understanding SOPs, where participants are educated about the new standard procedures, including how to record data, verification steps, and error reporting mechanisms. Second, training on the use of digital technology, which involves the use of automated sensors and monitoring dashboards, as well as handling potential technical issues. Third, providing knowledge on best practices in data recording and reporting to ensure accuracy and consistency throughout the process. With comprehensive training, it is expected that each team member will be able to execute the new procedures and effectively utilize digital technology correctly (Sujadi, 2024).
3. Implementation of Digital Technology (Internet of Things) for Data Recording
   To reduce the reliance on error-prone manual input, Internet of Things (IoT) technology has been widely used for real-time monitoring of the environment, safety and production (Zhang et al., 2023). Digital technology can be applied in the recording of production data. The use of automated sensors and digital systems to record the number of trucks and the volume of coal at each hauling point allows the data to be directly stored in the system without human intervention. The technology is integrated with a dashboard monitoring and monitoring system that allows production and management teams to monitor data in real-time, detect non-conformities, and make corrections quickly. The application of this technology also reduces the time required for data reporting and improves overall operational efficiency.

Since 2022, PT. Bordun Indie has implemented a Fleet Management System based on IoT technology to monitor coal transportation activities from ROM stockpile to Port stockpile. This concept can also be applied to all mining activities in PIT Kress.

4. Routine Supervision and Audit.

   To ensure that the improvements made can be sustained and have a sustainable impact, periodic monitoring and audits are carried out in the recording and reporting process. The supervisory team is tasked with randomly checking the data that has been recorded by the operator and comparing it with data from the digital system. This audit aims to ensure that SOPs are followed correctly and that there are no significant deviations in the reported data (Lemke & Strulak-Wójcikiewicz, 2021). Manual recording needs to be continued until the digital system can run as well as expected.

Research is still ongoing to this day. To assess the success of this improvement, a discussion was carried out with the Operational Control Centre team. The implementation of digitalization, process standardization, and continuous monitoring is predicted to reduce the deviation to close to 3%. Digitalization will reduce errors caused by human factors, while standardization of procedures will improve methodologies and reduce deviations (Fauzi, 2020). In addition, training for operators and teams involved in data processing will improve their understanding of procedures and the importance of data accuracy (Firoozi et al., 2024).

Control

At this stage, control measures are implemented to maintain the consistency and accuracy of coal production data recording, as well as prevent the recurrence of significant deviation problems. Good controls will ensure that repairs are not only temporary but become an integral part of the operational process.

1. Implementation of Process Control through Procedures and Monitoring

   To keep the procedures that have been implemented consistently followed by all operators, a continuous monitoring system has been created. Procedures are used as a standard reference in every production recording and reporting activity, and operators are required to undergo regular refreshment training sessions. The dashboard-based real-time monitoring system allows production and management teams to monitor the recording data in real-time. Deviations from the record-keeping standards can be detected quickly and corrective action can be taken immediately.

2. Using Control Charts to Monitor Recording Performance

   Control charts are used as statistical control tools to monitor variations in production, recording data continuously. This graph helps the team to identify if there is a trend of deviation or fluctuations that go out of the predetermined control limits. By using control charts, teams can immediately know if there are anomalies that require intervention before they further impact the accuracy of production data. If the monthly deviation is greater than 5% or less than -5%, then the cause of the deviation needs to be known for improvement. The scatter plot can be used as another indicator to monitor the deviation between these two methods. If the R squared is less than 0.95, then it is necessary to explore further the cause of the deviation. However, if the R squared is above 0.95, then the deviation is acceptable. Continuous analysis of the control chart data also helps dynamically adjust the process according to field conditions.

3. Periodic Data Audit and Performance Evaluation
   The routine audit process of recording and reporting production data continues as part of the control measures. Audits are carried out randomly and scheduled to ensure that the data reported is in accordance with conditions in the field and follows the standards that have been set. The audit results are used to provide feedback to operators and management regarding compliance with procedures and the effectiveness of the implemented recording system. This performance evaluation is also the basis for making continuous improvements and identifying areas that need further improvement (Nurazizah, 2018).
4. Formation of Supervisory Team and Feedback Loop
   A supervisory team was formed to monitor SOP compliance and implement process control. This team is tasked with providing guidance to operators, managing data from the monitoring system, and analyzing detected deviations (Ummah, 2024). The structured feedback loop allows operators to report on obstacles encountered in the recording process, and management can quickly take the necessary corrective steps. This system also encourages the active involvement of operators in maintaining the quality of production data.

CONCLUSION

The conclusion of this research shows that the truck count method has a greater variance than the topographic survey, indicating the need for improved accuracy in estimating coal production at Kress Pit, PT Bordun Indie. The main causes of this discrepancy are human error due to non-standardized recording procedures, the use of manual methods, and the use of external reference-based truck factors that do not match the site conditions. The proposed solutions include standardization of procedures through SOPs, specialized training, implementation of IoT technology for real-time data collection, and regular audits to improve data reliability and operational efficiency. This research contributes to future research as a foundation for the implementation of a more accurate production recording system in the mining industry. However, the scope was limited to the Kress Pit, so the findings need to be tested in other mining areas to examine their applicability under various operational conditions. Long-term research into the impact of digitization, particularly the integration of IoT technologies, is expected to reveal the huge potential for improving the efficiency and accuracy of production data, providing strategic insights for the management of the mining industry at large.

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