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Utilization of Software for Employee Working Time Efficiency and Accuracy of Coal Reserve Calculation

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Abstract

Background: Digital transformation in the mining sector has increasingly encouraged the adoption of specialized software to improve operational performance, particularly workforce time efficiency and the precision of technical calculations.
Objective: This study aimed to evaluate the effect of mining software utilization on employee working time efficiency and the accuracy of coal reserve calculations, addressing a research gap in systematically examining these relationships within open-pit mining operations.
Methods: This study employed an integrated quantitative–qualitative approach using a comparative method between manual work processes and software-based processes. The analysis used geological data, topographic data, and mining technical parameters from open-pit mining operations. Data processing was conducted using MineScape to simulate mine planning and reserve estimation, and the results were compared with those obtained through previously used conventional methods.
Results: The results indicated that software utilization significantly reduced job completion time and improved the consistency and accuracy of reserve calculation results. In addition, more systematic data integration through software helped minimize potential calculation errors and accelerate the decision-making process.
Conclusion: This study concluded that the utilization of mining software had a positive impact on improving work efficiency and the accuracy of coal reserve calculations. Therefore, the implementation of software-based technology is considered a relevant strategy for supporting performance optimization and competitiveness in the mining industry in the digital era.

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INTRODUCTION

The rapid development of digital technology has fundamentally transformed numerous industrial sectors, including the coal mining industry, which is now compelled to operate with greater speed, precision, and efficiency (Litvinenko, 2020; Majeed & Iftikhar, 2026; Wang et al., 2022). Mining operations no longer rely exclusively on conventional methods; rather, they increasingly use specialized mining software to support planning, data processing, geological modeling, and coal reserve estimation (Nagovitsyn & Lukichev, 2025; Quansah & Yakin, 2025). The adoption of software in mining activities is widely recognized as a means of increasing workforce productivity, as data can be processed automatically, systematically, and in an integrated manner (Bhattacharyya & Shah, 2022; Flores-Castañeda et al., 2025). Furthermore, the use of software enables companies to substantially minimize calculation errors that commonly occur in manual workflows, particularly in coal reserve estimation activities that require a high

degree of precision (Suparno et al., 2025).

According to Laudon (1996), the application of information technology in companies can improve operational efficiency and the quality of decision-making. In the context of mining, software is an important tool for supporting the effectiveness of technical and administrative work.

Work time efficiency is one of the primary indicators used to evaluate employee performance in mining companies (Gackowiec et al., 2020; Zhou et al., 2024). The faster a task can be completed without compromising the quality of the results, the higher the level of efficiency achieved. The use of mining software allows data processing activities that previously required a long time to be completed more quickly because most calculations are performed automatically by the system. This is in line with the opinion of Arifin (2019), who stated that computer-based information systems can increase the speed of data processing and organizational work productivity. In coal reserve estimation activities, mining software such as Surpac, MineScape, and Minex can assist employees in conducting geological modeling, volume calculations, and reserve analysis more efficiently than manual methods (Mamba et al., 2023; Sharma et al., 2023). This condition indicates that software utilization has a significant influence on work time effectiveness in mining companies (Lööw, 2022).

Beyond time efficiency, the accuracy of coal reserve calculations is a critical factor because it is directly related to corporate decision-making, production planning, and the economic valuation of mining assets (Krisna & Faturohman, 2021; Saługa et al., 2020). Inaccuracies in reserve estimates can result in significant corporate losses from both operational and financial perspectives. Therefore, mining companies require technology capable of producing data with a high level of accuracy. According to Darling (2011), coal reserve estimation must be conducted using accurate and accountable methods because the estimation results serve as the basis for mining activities. The use of mining software is considered capable of increasing accuracy because data processing is performed using algorithms and mathematical models that are more measurable than manual calculations. In addition, software can integrate geological, topographic, and drilling data in greater detail, making reserve estimation results more representative of actual field conditions.

Although mining software has been widely adopted across the industry, many companies have not yet achieved optimal utilization of these technologies (Barnewold & Lottermoser, 2020; Ediriweera & Wiewiora, 2021; Sishi & Telukdarie, 2020). Some employees still rely on manual data processing methods due to limited software proficiency or inadequate institutional support and infrastructure. This situation leads to slower workflows and increases the risk of computational errors. Therefore, research on the influence of software utilization on work time efficiency and the accuracy of coal reserve calculations remains necessary to determine the extent to which technology has a real impact on improving the operational performance of mining companies. In addition, this research is important as evaluation material for companies seeking to improve the quality of human resources and optimize the use of digital technology in the mining sector.

Based on these problems, this study aims to analyze the influence of software utilization on employee work time efficiency and the accuracy of coal reserve calculations. This research is expected to contribute to the development of knowledge in the mining sector and serve as a reference for companies seeking to enhance work effectiveness and the quality of reserve calculations through the application of appropriate information technology.

Figure 1. User interface display

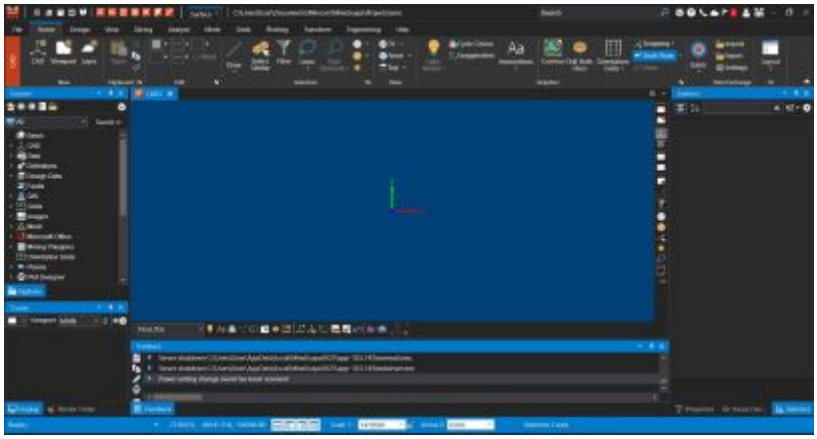

Figure 2. Working area display

A review of the existing literature revealed a research gap in the systematic examination of how mining software specifically affected both workforce time efficiency and the precision of coal reserve estimation simultaneously in open-pit mining contexts. Most prior studies addressed either operational efficiency or estimation accuracy in isolation, and few focused on the Indonesian mining industry. The novelty of this study lay in its integrated mixed-methods examination of Minescape software implementation, which uniquely combined quantitative comparative measurements of work duration and estimation error rates with qualitative analysis of user experience and operational workflows, thereby providing a more comprehensive empirical basis for evaluating software-driven digitalization in coal mining operations.

METHOD

This study employed an integrated mixed-methods approach, combining quantitative comparative analysis with qualitative descriptive observation, to examine the influence of software utilization on employee working time efficiency and the accuracy of coal reserve calculations in mining companies. The qualitative component was used to understand the process of software use, user experience, and changes in work effectiveness following technology adoption in mining operations, while the quantitative component enabled comparative measurement of work duration and estimation accuracy before and after software implementation. The research was carried out through direct observation and experimentation using mining software in data processing, geological modeling, and coal reserve estimation, allowing the researchers to understand actual field conditions in depth.

The data used in this study consisted of primary and secondary data. Primary data were obtained through field observations, in-depth interviews with employees and the company's technical team, and documentation of the mining software utilization process. Observations were carried out to examine the stages of employee work before and after the use of the software, while interviews were conducted to obtain information about the benefits of the software, obstacles to

its use, and its effects on work efficiency and accuracy. Secondary data were obtained from company documents, coal reserve estimation reports, drilling data, topographic data, company operational standards, and scientific literature related to information technology and mining software.

Data collection techniques included participatory observation, semi-structured interviews, documentation, and literature review. Participatory observation was carried out by directly observing the work processes of employees using mining software to process coal reserve data. Semi-structured interviews were conducted with software operators, geologists, mine engineers, and management to obtain data on the effectiveness of the software in supporting technical work. Documentation was carried out by collecting reserve estimation results, work duration records, photos of research activities, and mining model outputs generated by the software. The literature review was used as a theoretical basis to support the research results and discussion.

The data analysis technique used an interactive analysis model consisting of data reduction, data presentation, and conclusion drawing. Data from observations, interviews, and documentation were selected and grouped according to the research focus. Furthermore, the data were presented in descriptive form, tables, research flow diagrams, and comparative graphs of observation results. The final stage involved drawing conclusions based on the relationship between the research findings regarding the influence of software use on working time efficiency and the accuracy of coal reserve calculations. Data validity was ensured through source triangulation and methodological triangulation by comparing the results of observations, interviews, and documentation.

The measurement of variables in this study was carried out based on indicators directly observed during the research process. Software utilization was measured through ease of use, data processing speed, mine model visualization capability, and software effectiveness in supporting technical decision-making. Working time efficiency was measured through changes in work duration before and after software use and employees' perceptions of the acceleration of the work process. The accuracy of coal reserve calculations was measured based on the accuracy level of estimation results, minimization of calculation errors, and the suitability of estimation results with actual field conditions based on user evaluations and company documents.

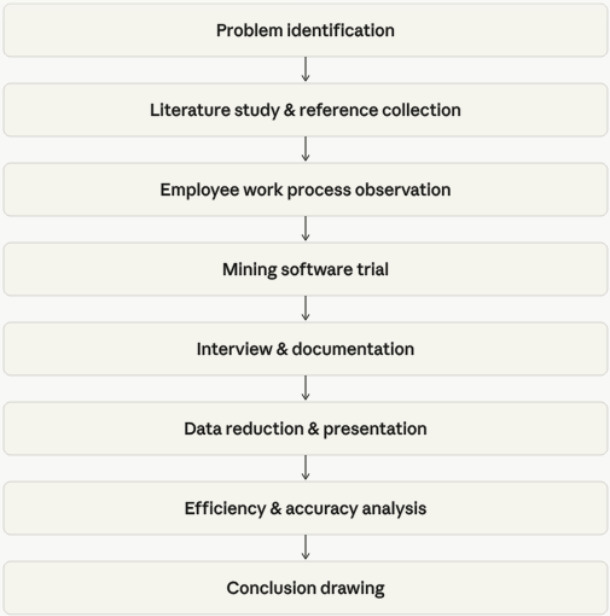

Figure 3. Research Flow

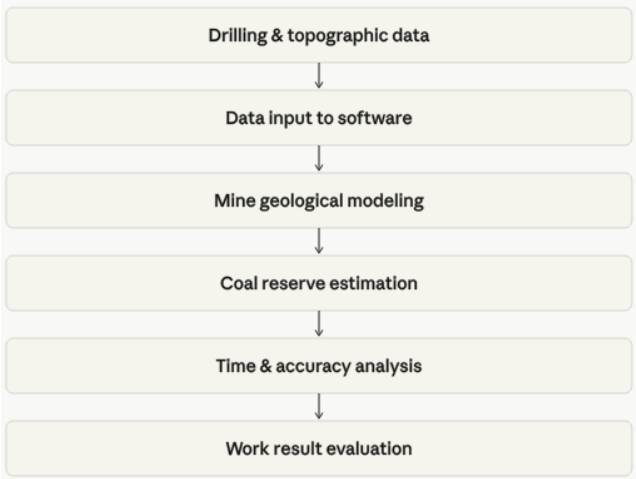

Figure 4. Flow of Software Use in Research

Table 1. Data Types and Sources

Data Type	Data Source	Collection Techniques
Primary Data	Field observations and employee interviews	Observations and interviews
Secondary Data	Corporate documents and backup reports	Documentation
Supporting Data	Books, journals, and scientific literature	Literature study

Table 2. Data Types and Sources

Variable	Indicator	Measurement Techniques
Software Utilization	Ease of use, speed of data processing, visualization of the model	Observations and interviews
Work Time Efficiency	Length of time to work	Observations
Accuracy of Backup Calculations	Accuracy of estimation results and minimization of errors	Documentation and observation

RESULTS AND DISCUSSION

Results

This study was conducted to analyze the effect of mining software utilization on employee working time efficiency and the accuracy of coal reserve calculations in open-pit mining operations. Based on field observations, interviews, and documentation of data processing before and after the use of MineScape software, the findings indicated that software utilization significantly improved workflow speed and the quality of calculation results.

Before the software was used, coal reserve data processing was conducted manually using basic spreadsheet calculations, with topographic, drilling, and geological data processed separately. This condition caused the work process to take a relatively long time because employees had to repeatedly recheck the data to ensure the accuracy of the calculation results. In addition, differences in data formats often caused delays in data integration and evaluation of the estimated results.

After MineScape software was implemented, the data processing became more integrated because all technical data could be input and processed within the same system. Employees were able to perform geological modeling, overburden volume calculations, and coal reserve estimation automatically using the features available in the software. Based on the observation results, software utilization accelerated the work process, particularly in the stages of drilling data processing, coal seam modeling, and reserve volume calculation. The following table presents a comparison of the average working time before and after the use of the software.

Table 3. Comparison of Working Time Before and After Using Software

Job Type	Manual Method	Using the Software	Time Efficiency
Drilling data	6 hours	2 hours	66,7%

processing			
Geological modeling	8 hours	3 hours	62,5%
Coal reserve calculation	10 hours	4 hours	60,0%
Creation of technical reports	5 hours	2 hours	60,0%

The results showed that working time efficiency increased significantly after the use of mining software. The reduction in processing time occurred because the software was able to perform calculation and data visualization processes automatically, so employees did not need to perform repetitive calculations manually.

In addition to improving working time efficiency, this study also found an increase in the accuracy of coal reserve calculations. Based on the evaluation of reserve estimation results between manual and software-based methods, the use of software resulted in a lower calculation error rate than conventional methods. This occurred because the software used more systematic mathematical models and calculation algorithms, making the estimation results more consistent. The following table shows a comparison of the accuracy rates of the reserve estimation results.

Table 4. Comparison of Coal Reserve Calculation Accuracy

Calculation Method	Estimation Error Rate	Accuracy Rate
Manual	8,5%	91,5%
Software Minescape	2,1%	97,9%

The results of interviews with mine employees and engineers showed that the software helped improve work accuracy because the data used could be visualized as three-dimensional models. This visualization made it easier for users to evaluate coal seam conditions, seam thickness, and reserve boundaries in greater detail. In addition, data integration within the software simplified the model revision process when changes occurred in drilling or topographic data.

Based on the study results, the use of mining software also had a positive impact on the technical decision-making process. Estimated data could be obtained more quickly, allowing the company to evaluate production, mine planning, and operational control more effectively. Thus, the use of software not only improved employee work efficiency but also supported the optimization of the company's overall performance.

Discussion

The findings demonstrate that mining software has a significant positive influence on employee working time efficiency, consistent with information systems theory as articulated by (Laudon & Laudon, 1996). By enabling automated and integrated data processing, the software substantially reduces task completion time across all examined workflow stages. This finding is also in line with the information systems theory proposed by Laudon (1996), which states that the application of information technology can improve organizational operational efficiency by accelerating data processing and information integration.

This efficiency gain is evidenced by substantial reductions in processing time for drilling data handling, geological modeling, and reserve estimation tasks. Manual workflows, which are sequential and require repetitive verification, are inherently susceptible to delays. In contrast, MineScape consolidates technical data within a unified platform, thereby accelerating processing and eliminating redundant rechecking.

Regarding calculation accuracy, the data reveal a marked improvement when software-based methods are employed. The elevated error rate inherent in manual approaches, attributable to reliance on individual computational accuracy and susceptibility to human error, is substantially mitigated by MineScape's algorithmic processing and digital geological modeling, which produce results that more accurately represent actual field conditions.

These findings support the opinion of Darling (2011), who stated that coal reserve estimation requires an accurate and accountable calculation method because the estimation results serve as the main basis for mining decision-making. In this study, the use of MineScape software was proven to reduce the estimation error rate to below 3%, making the calculation results more accurate than those obtained using manual methods.

In addition to improving efficiency and accuracy, mining software also provides benefits in data visualization and technical decision-making. The software's three-dimensional visualization feature helps engineers and geologists understand coal seam conditions in greater detail, allowing the reserve evaluation process to be carried out more quickly and precisely. This shows that software functions not only as a calculation tool but also as a medium for analysis and support for company operational decisions.

This study also found that the success of software implementation is influenced by the ability of human resources to operate the technology. Several obstacles identified during the study included a lack of training in software use and the limited experience of some employees in digital data processing. This condition shows that technology implementation must be supported by improvements in human resource competence so that the benefits of software can be maximized.

In terms of research novelty, or state of the art, this study differs from previous research because it not only discusses the influence of technology on work efficiency in general but also specifically examines the relationship between the use of mining software and the accuracy of coal reserve estimation in open-pit mining activities. This study also integrates technical aspects of mining with an operational management approach, thereby providing a new perspective on the importance of digitalization in improving work effectiveness and quality in the mining sector.

The results of this study strengthen the concept that mining digitalization is a strategic necessity in facing modern industrial competition. Companies that can optimize the use of mining software will gain advantages in operational efficiency, production planning precision, and decision-making speed. Therefore, the application of software-based technology is an important factor in supporting the sustainability and competitiveness of mining companies in the digital industrial era.

CONCLUSION

Based on the findings, the use of mining software positively influenced employee working time efficiency and the accuracy of coal reserve calculations. The use of MineScape software accelerated the processing of drilling data, geological modeling, reserve estimation, and technical report preparation compared with manual methods. Working time efficiency improved because data calculation and integration processes were automated, reducing processing time and potential work delays.

In addition to improving work efficiency, software use was also proven to increase the accuracy of coal reserve calculations. The integrated data processing system and mathematical models embedded in the software minimized calculation errors and produced more consistent estimates. The three-dimensional model visualization available in the software also supported reserve evaluation and technical decision-making more effectively.

Theoretically, this study contributed to the development of operational management and mining technology studies, particularly regarding the influence of digitalization on work effectiveness and the quality of technical data processing. Practically, the findings may serve as a consideration for mining companies in increasing software utilization as a strategy to improve productivity, operational efficiency, and decision-making quality.

This study had several limitations. First, it focused exclusively on a single mining software platform, MineScape, which limited the generalizability of the findings to other software environments. Second, the scope of the study was geographically and operationally limited, restricting the extent to which the results could be extrapolated to broader industry contexts. Therefore, future research is recommended to adopt a quantitative approach involving larger, probabilistically sampled respondent groups and to conduct systematic comparative analyses across multiple mining software solutions to generate more comprehensive and generalizable insights.

Mining companies are strongly advised to prioritize systematic training and competency

development programs for employees in the operation of mining software, ensuring that technology investments translate into optimal operational outcomes. Moreover, the sustained integration of digital technologies into corporate management systems is essential for advancing the effectiveness, efficiency, and competitiveness of mining operations in an increasingly digitalized industry landscape.

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed significantly to this study: Denny Boy Sitanggang led conceptualization, methodology, and project coordination; I Dewa Ketut Kerta Widana focused on data collection and analysis; Dewi Puspaningtyas Faeni contributed to literature review and manuscript drafting. All authors reviewed and approved the final manuscript and are accountable for the integrity and accuracy of the work.

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