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# Productivity and Cost Analysis of Drilling for Blast Holes in Granite Mining at PT. Hansindo Mineral Persada

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**ABSTRACT**

Granite's durability makes it a popular choice in construction, but efficient granite mining, especially through drilling for blast holes, is essential for productivity and cost management. PT. Hansindo Mineral Persada in Kalimantan Barat faces challenges balancing drilling efficiency and costs, requiring a detailed study to optimize operations. This article presents a study analyzing drilling machine productivity, focusing on the rotary-percussive method based on 2022 drilling costs. The study revealed insights into drilling productivity, obstacles, and costs. Notably, productivity, measured by Net Penetration Rate (NPR) and Gross Penetration Rate (GPR), showed significant improvements: NPR for machine 001 increased from 71.39 m³/hour to 95.24 m³/hour, and GPR from 58.02 m³/hour to 75.35 m³/hour. Machine 002's NPR improved from 53.49 m³/hour to 60.22 m³/hour, with GPR rising from 44.47 m³/hour to 46.25 m³/hour. Avoidable obstacles decreased, but unavoidable ones persisted. Drilling costs varied, with machine 001's cost decreasing from Rp 68,857 to Rp 58,873 per meter and machine 002's increasing from Rp 81,324 to Rp 86,022. Recommendations include improved planning, regular maintenance, and better scheduling. Future research on rock properties, equipment age, and tool quality could further enhance productivity and efficiency.

**Keywords**: *Granite mining efficiency, Drilling productivity, Rotary-percussive method, Cost management, Operational optimization*.

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## 1. Introduction

Granite is one of the most widely used construction materials due to its durability and aesthetic appeal (Careddu, 2020; Costa et al., 2021). The extraction of granite through mining processes, particularly drilling for blast holes, plays a critical role in producing this material (Baia, 2021; Naidu et al., 2021). Drilling for blast holes in granite mining is a complex process that involves several factors, including the type of equipment used, drilling techniques, rock properties, and the skill level of the operators (Nikkhah et al., 2022; Adebayo et al., 2023). Each of these factors can significantly affect the speed and efficiency of the drilling process and the overall cost of operations (Gooneratne et al., 2020; Teodoriu & Bello, 2021). Inefficient drilling can lead to increased fuel consumption, higher equipment wear and tear, and operational costs (Pamenov et al., 2022). Therefore, understanding and optimizing the factors that influence drilling productivity is essential for the economic viability of the mining operation.

PT. Hansindo Mineral Persada (PT Hansindo) is a company engaged in granite mining, operating in Peniraman, one of the villages in Sungai Pinyuh Subdistrict, Mempawah Regency, Kalimantan Barat Province. It is the only company that has remained operational and active in the Mempawah area since 2011 and continues to operate (2022) (ESDM, 2022). PT Hansindo Mineral Persada employs an open-pit mining system using the quarry method. The mining activities include overburden removal, rock blasting, loading, transportation, and crushing (size reduction) according to market demands. The entire production process will be affected if these activities are disrupted. PT. Hansindo Mineral Persada has been facing challenges in maintaining a balance between productivity and cost in its drilling operations. With the rising cost of fuel and equipment maintenance, the company is under pressure to improve the efficiency of its drilling processes without compromising on the output quality. This has led to the need for a comprehensive analysis of the current drilling operations to identify areas where improvements can be made. The company is particularly interested in understanding how different drilling techniques and equipment configurations can be optimized to enhance productivity while reducing costs.

Previous mining studies have shown a significant correlation between drilling efficiency and overall costs (Samatemba et al., 2020; Shcherbakov et al., 2021). However, these studies have often been conducted in different geological settings, and their findings may not directly apply to the specific conditions at PT. Hansindo Mineral Persada. The unique characteristics of the granite at this site, including its hardness and fracture patterns, require a tailored approach to drilling that considers the specific challenges posed by the local geology. Therefore, there is a need for a detailed study that focuses on the particular conditions of granite mining at PT. Hansindo Mineral Persada.

This article presents the results of a study conducted at PT Hansindo Mineral Persada to analyze the productivity of drilling machines in providing blast holes and the factors influencing this productivity. The study focused specifically on the rotary-percussive drilling method. Additionally, the analysis is based on the actual drilling costs in 2022 and does not cover the scope of occupational health and safety in drilling operations.

## 2. Materials and Methods

### 2.1. Study Area

The research was conducted at the project site of PT Hansindo Mineral Persada, located in RT 021/RW 10, Dusun Gambir, Desa Peniraman, Sungai Pinyuh Subdistrict, Pontianak Regency. The research location is accessible by both four-wheel and two-wheel vehicles, with the following routes: (a) Pontianak - Sungai Pinyuh: approximately 2 hours by land transportation, (b) Sungai Pinyuh - Desa Peniraman: approximately 30 minutes by land transportation. The mining site of PT Hansindo Mineral Persada can be reached from Supadio Airport by land, passing through two administrative boundaries, namely Kubu Raya Regency and Pontianak City, before continuing to Mempawah Regency. To reach the research location, both four-wheel and two-wheel vehicles can reach Desa Peniraman, with a travel distance of approximately 2 km. From the provincial road to the research site, the road is compacted dirt, with a travel distance of approximately 2 km. The transportation infrastructure from Supadio Airport, located in Kubu Raya Regency, to Desa Peniraman, consists mainly of well-paved asphalt roads, with hot mix conditions along the provincial or national roads.

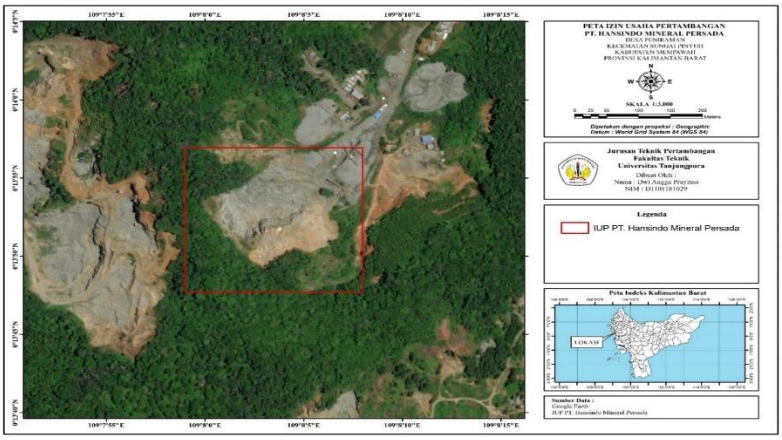


**Figure 1.** Study Area

### 2.2. Data

The data used in this study are primary and secondary. Primary data is collected directly from the field according to the research needs. The data collected directly in the field includes (a) drilling geometry: Blast hole depth, burden, and spacing between blast holes. This is intended so that the research can determine the factors that can be used for comparison in drilling activities. (b) cycle time: This data includes the cycle time of the drilling machine used in drilling activities. This data is obtained through direct observation in the field. Once the data is obtained, cycle time can be calculated using the formula: Ct = Pt + Bt + St + Dt, (c) the amount of fuel and lubricants used in drilling activities in the field, and (d) rock properties: the collection of this data includes the physical and mechanical properties of the rocks at the research site. These data will compare the physical and mechanical properties of the tool's compelling performance.

Secondary data is required by the researcher and obtained directly from the company or existing literature. The required data includes (a) available work time: the collection of data includes the work time provided by the company and the actual time used by the operator in drilling activities; (b) drilling tool specifications: the collection of this data includes the specifications of the tools used in drilling activities. Once this data is obtained, it will be compared with the adequate performance of the tool, (c) drilling equipment: the collection of this data includes the cost of the drilling machine, compressor cost, fuel cost and type of fuel used, the cost of drill rods, drill bits, and couplings used to support drilling activities, and (d) labor wages: the collection of this data aims to determine the drilling labor wages at PT. Hansindo Mineral Persada.

### 2.3. Analysis Method

#### 2.3.1. Equipment Availability

Calculations are made using data obtained directly from the field to determine the productivity of the drilling machine. Equipment availability is determined after analyzing the available work time and the actual work time of the equipment (Sherafat et al., 2020; Wong et al., 2020). The key metrics include Mechanical Availability, Physical Availability, Use of Availability, and Effective Utilization. These metrics are calculated using the following equations (Prodjosumarto, 1996):

a. **Mechanical Availability (MA)**: This metric indicates the actual condition of the equipment being used and is analyzed using the following equation:

$$MA = \frac{W}{W + R} \times 100\% \quad (1)$$

b. **Physical Availability (PA)**: This metric provides a record of the physical state of the equipment being used and is analyzed using the following equation:

$$PA = \frac{W + S}{W + S + R} \times 100\% \quad (2)$$

c. **Use of Availability (UA)**: This metric expresses the percentage of time an equipment is used for operation when it is available for use and is analyzed using the following equation:

$$UA = \frac{W}{W + S} \times 100\% \quad (3)$$

d. **Effective Utilization (EU)**: This metric shows how much of the total available work time is utilized for productive work and is analyzed using the following equation:

$$EU = \frac{W}{W + S + R} \times 100\% \quad (4)$$

Where:

| | | |
|---|---|---|
| EU | : | Effective Utilization |
| W | : | Working hours, or the total working hours of the equipment, are the time the operator uses for drilling activities. |
| R | : | Repair hours, or total repair hours, are the time spent on repairs and the time lost due to waiting during repairs, including spare parts provision and maintenance. |

| | | |
|---|---|---|
| S | : | Standby hours or the total hours when the equipment cannot be used, even though it is not broken (ready to operate), such as during heavy rain, unprepared work sites, or breakdowns of the drilling machine. |
| W + S + R | : | Scheduled hours or the total working hours during which the drilling machine is scheduled to operate |

Drilling Machine Productivity: The data related to the productivity of the drilling machine includes drilling speed, equivalent volume, and work efficiency. The productivity data can be expressed in $m^3/m$, and once these data are obtained, the following formula is used:

### 2.3.2. Cycle Time

The cycle time of the drilling process refers to the total time required to complete one entire drilling cycle, from the start of the drilling operation to the point where the process can be repeated (Wodecki et al., 2020; Dupriest & Noynaert, 2022). The calculation of cycle time for the drilling machine is conducted by observing the movement pattern of the drilling machine during its operation. The calculation uses the following equation: $Ct = Pt + Bt + St + Dt$..........................................................(5)

Ct : The cycle time of the drilling process
Pt : Positioning time: the time taken for the drilling machine to move to the drilling point
Bt : Drill time: the time required to penetrate the rock to the depth of the blast hole.
St : Stop time: The time spent blowing cuttings, lifting, detaching, and connecting drill rods.
Dt : Delay time: The time taken to overcome obstacles.

### 2.3.3. Drill Rig Productivity

Drill rig productivity refers to a drilling rig's efficiency and effectiveness in terms of how much material it can drill through over a specific period of time. It is a key performance indicator in drilling operations, often used to assess the performance of the drilling equipment and the overall operation (Mathur et al., 2020; Barakat et al., 2021).

Drill Rig Productivity: Data related to drill rig productivity includes drilling speed, equivalent volume, and work efficiency. Productivity data can be expressed in $m^3/m$, and after obtaining the following data, the formula used is as follows: $P=Drr \times Veq \times Ek \times 60$................................................................(6)

P : Drill rig production ($m^3/min$)
Drr : Average drilling speed (m/min)
Veq : Equivalent volume ($m^3/m$)
Ek : Drilling work efficiency (%)
60 : 1 hour expressed in minutes

### 2.3.4. Work Efficiency

Work efficiency is the ratio of the productive time spent on a task to the total time available or scheduled for that task, usually expressed as a percentage. It indicates how effectively time and resources are used to complete a specific job or set of tasks (Barosz et al., 2020; Johari & Jha, 2020). Work Efficiency: This data is obtained by comparing the available working time with the actual working time used by the operator during the drilling activities. Work efficiency can be expressed as a percentage (%). After obtaining the following data, it can be calculated using the formula:

$$Ek = \frac{WP}{WT} \times 100\% \qquad (7)$$

Ek : Drilling work efficiency (%)
WP : Time used for drilling work (minutes)
WT : Total scheduled working time (minutes)

### 2.3.5. Drilling Speed

Drilling speed refers to the rate at which a drill penetrates a material or surface, typically measured in meters per minute (m/min) or feet per minute (ft/min). It indicates how quickly a drill bit advances into the material being drilled, and it is a crucial factor in evaluating the efficiency of drilling operations (Al-Shargabi et al., 2023; Kingslin, 2023). Drilling Speed (Drr): This data represents the speed of the drilling machine in creating blast holes. It is obtained from direct field observations and can be expressed in meters per minute. Drilling speed can be calculated using net and gross penetration rates.

**a. Net Penetration Rate (NPR)**

Net Penetration Rate (NPR) measures the drilling speed during the drilling process, excluding any non-productive time. It represents how quickly the drill bit penetrates the drilled material when actively drilling without accounting for delays, setup, or downtime.

$NPR = \frac{h}{B_t}$ (meters/minute)..........(8)

h : Depth of the borehole (meters)
Bt : Time to penetrate the rock to the depth of the blast hole (minutes)

**b. Gross Penetration Rate (GPR)**

$GPR = \frac{h}{C_t}$ (meters/minute)

h : Depth of the borehole (meters)
Bt : Cycle time (minutes)

From these calculations and direct field observations, the productivity of the drilling process and the factors that may hinder the drilling activities for blast holes at PT can be determined. Hansindo Mineral Persada.

### 2.3.6. Ownership Cost

Ownership Cost refers to the total expenses associated with owning a piece of equipment or machinery over its lifespan. These costs exceed the initial purchase price and include all the ongoing expenses required to keep the equipment operational and in good condition (Burnharm et al., 2021; Liu et al., 2021).

To determine the ownership costs associated with the drilling activities, calculations are made based on data obtained from direct field observations, including:

a. **Depreciation of Equipment**

Depreciation Cost of Equipment refers to the reduction in the value of equipment over time due to factors such as wear and tear, aging, and obsolescence. Depreciation is an accounting method used to allocate the cost of the equipment over its useful life, reflecting its gradual decline in value as it is used. Equipment invested in drilling activities is depreciated. Critical aspects of depreciation expenses include;

*(1) Straight-Line Depreciation*

This method evenly spreads the cost of the equipment over its useful life.

$\text{Depreciation Cost per Year} = \frac{Initial\ Purchase\ Price - Residual\ Value}{Useful\ life\ (Years)}$..........(9)

*(2) Declining Balance Method:*

This method applies a constant depreciation rate to the equipment's book value each year, leading to higher depreciation costs in the earlier years.

Depreciation Cost = Book Value at the Beginning of Year × Depreciation Rate..........(10)

*(3) Units of Production*

Depreciation is based on the actual usage of the equipment, such as hours operated or units produced.

$\text{Depreciation Cost per Unit} = \frac{Initial\ Purchase\ Price - Residual\ value}{Total\ Expected\ Out}$..........(11)

b. **Bank Interest, Taxes, and Insurance:**

The bank interest depends on the current loan interest rate, while the remaining book value of the equipment determines taxes and insurance (Bigio & Sannikov, 2021; Hanzlík & Teplý, 2022). Generally, bank interest, insurance, and taxes can be calculated as follows (Wilopo, 2009).

$$\text{Interest, Insurance, Tax} = \frac{Factor \times Purchase\ Price \times Interest\ Rate}{Annual\ Operatimh\ Hours} \quad (12)$$

$$\text{Factor} = 1 - \frac{(n-1)(1-r)}{2n} \quad (13)$$

n : Economic life of the equipment (years)

r = $\frac{Residual\ value}{Capital\ value}$

c. **Total Owner Cost**

Total Ownership Cost = Depreciation Cost of Equipment+Bank Interest, Taxes, and Insurance Cost

**2.3.7. Operational Cost**

Operational Cost, also known as operating cost, refers to the expenses incurred during the regular operation of equipment or machinery. These costs are necessary to keep the equipment functional and productive and are associated with the day-to-day operations of a business or project.

Critical components of operational cost include:

a. **Maintenance cost**

Maintenance costs include drill bit, coupling, and drill rod maintenance. Drill bit maintenance consists of

(1) Drill bit maintenance = $\frac{Drill\ bit\ price}{Useful\ life}$ (14)

(2) Coupling bit maintenance = $\frac{Coupling\ price}{Useful\ life}$ (15)

(3) Drill Rod Maintenance = $\frac{Drill\ rod\ price}{Useful\ life}$ (16)

Total Maintenance Cost = Drill Bit Maintenance+Coupling Maintenance+Drill Rod Maintenance

b. **Fuel costs**

Fuel Cost is the expense incurred to purchase fuel required for operating equipment, machinery, or vehicles (Wargula et al., 2020; Islam et al., 2021). It is a critical component of operational costs, particularly for industries that rely heavily on fuel-powered equipment, such as construction, mining, transportation, and agriculture. Fuel cost is directly related to the equipment's consumption rate and fuel price, which can fluctuate due to market conditions, geopolitical factors, and supply and demand dynamics.

Fuel Cost (FC) = Fuel Requirement + Fuel Price (17)

c. **Lubricant Costs**

Lubricant Costs refer to the expenses associated with purchasing and applying lubricants, such as oils, greases, and other fluids, that are necessary to maintain the smooth operation of machinery and equipment (Wagula et al., 2020; Islam et al., 2021). Lubricants are crucial for reducing friction, preventing wear and tear, and extending the lifespan of mechanical components. Managing lubricant costs is essential for maintaining equipment efficiency and minimizing downtime in various industries, including construction, mining, manufacturing, and transportation. Included in lubricant costs are grease and engine oil, which can be calculated by

Grease Cost = Grease Requirement x Grease Price (18)

Engine Oil Cost = Engine Oil Requirement x Engine Oil Price (19)

So that total lubricant cost = Grease Cost + Engine Oil Cost....................................................(20)

d. **Operator costs**

Operator Cost refers to the expenses associated with employing personnel to operate machinery and equipment in various industries, such as construction, mining, manufacturing, and transportation. These costs are a crucial part of the overall operational expenses for any business that relies on skilled workers to run equipment and perform essential tasks.

Operator Salary = $\frac{Monthly\ Salary}{Working\ Days\ per\ Month}$..................................................................(21)

Thus, the Total Operational Cost can be calculated with equation (22).

Total Operational Cost = Total Maintenance Cost+ Fuel Cost + Lubricant Cost + Operator Salary ...........................................................................................(22)

## 3. Result and Discussion

Based on the research conducted on drilling activities at PT. Hansindo Mineral Persada, several relevant findings were obtained regarding the productivity of drilling machines, the obstacles encountered during drilling activities, and the actual drilling costs. From these findings, it can be understood that drilling productivity and efficiency are significantly influenced by drilling speed, the type of obstacles encountered, and the operational cost management strategies. This study used two leading indicators to measure the productivity of drilling machines: Net Penetration Rate (NPR) and Gross Penetration Rate (GPR). According to the analysis results, for machine 001, the drilling productivity based on NPR speed in the first activity was 71.39 m³/hour, which increased to 95.24 m³/hour in the third activity. Meanwhile, for machine 002, productivity was recorded at 53.49 m³/hour in the second activity, increasing to 60.22 m³/hour in the third activity. The measurement of productivity using GPR showed slightly lower results. For machine 001, productivity in the first activity was 58.02 m³/hour and increased to 75.35 m³/hour in the third activity. Meanwhile, for machine 002, productivity was recorded at 44.47 m³/hour in the second activity and increased to 46.25 m³/hour in the third activity.

From these results, it can be concluded that there was a significant increase in productivity from one drilling activity to the next for both machines, whether measured using NPR or GPR. This increase indicates an improvement in operational efficiency, which may be due to adjustments in drilling techniques, enhancement of operator skills, or perhaps more favorable field conditions in subsequent activities. However, the study also revealed various obstacles that affect the drilling process. These obstacles were categorized into two types: avoidable and unavoidable obstacles. For machine 001, in the first activity, avoidable obstacles were recorded at 22.92 minutes per day, while unavoidable obstacles were recorded at 51.06 minutes per day. In the second activity for machine 002, avoidable obstacles reached 26.72 minutes per day, and unavoidable obstacles were recorded at 45.04 minutes per day. In the third activity, for machine 001, avoidable obstacles decreased to 7.44 minutes per day, and unavoidable obstacles decreased to 13.14 minutes per day. Conversely, machine 002 recorded avoidable obstacles of 19.57 minutes per day and unavoidable obstacles of 50.98 minutes per day. Further analysis showed that avoidable obstacles tended to decrease as the drilling activities progressed, indicating improved operational efficiency and possibly enhanced operator skills or better field conditions. However, unavoidable obstacles, such as weather conditions or unexpected mechanical issues, remain significant factors affecting productivity. Therefore, the company must develop more effective mitigation strategies to reduce these obstacles.

Additionally, the study provided insights into the actual drilling costs incurred. In the first activity with machine 001, the actual drilling cost was Rp 68,857 per meter. In the second activity with machine 002, this cost increased to Rp 81,324 per meter. Subsequently, in the third activity, the drilling cost with machine 001 decreased to Rp 58,873 per meter, but for machine 002, it increased to Rp 86,022 per meter. These cost variations could be attributed to several factors, including the efficiency of fuel usage, maintenance costs, and the frequency and type of obstacles encountered during drilling. Based on these findings, several recommendations are proposed to improve the efficiency and effectiveness of drilling. For the company, it is essential to conduct more thorough planning of drilling activities to enhance the performance of drilling machines. In addition, it is recommended that the company allocate specific time for regular maintenance of drilling machines and compressors and schedule fuel refills properly to avoid obstacles such as fuel shortages. Providing adequate spare parts for drilling machines and compressors is also essential to ensure optimal tool performance.

Future researchers are highly recommended to conduct further studies on rocks' physical and mechanical properties, drilling speed, and their impact on drilling productivity. This study could provide deeper insights into how geological characteristics affect drilling efficiency. Moreover, further research on the age of the equipment and tool quality is also essential to determine its impact on the productivity of drilling machines. With a better understanding of these factors, better strategies are expected to be developed to enhance drilling productivity and efficiency in the future.

This study indicates that many factors influence PT drilling productivity and operational costs. Hansindo Mineral Persada. Although there are some unavoidable obstacles, there are also many opportunities to improve efficiency through better planning, proper equipment maintenance, and more effective operational management strategies. By paying attention to these factors, the company can improve its drilling productivity and efficiency, reduce operational costs, and enhance the sustainability of its drilling operations in the future.

## 4. Conclusion

Based on the findings from the research conducted on the drilling activities at PT. Hansindo Mineral Persada, several key conclusions can be drawn about the factors influencing the productivity and efficiency of drilling operations. This study highlights that productivity, measured by the Net Penetration Rate (NPR) and Gross Penetration Rate (GPR), significantly varies depending on several operational and environmental factors. The increase in productivity from one drilling activity to the next suggests that enhancements in operational efficiency, adjustments in drilling techniques, and potentially favorable field conditions all contribute positively to the overall performance of the drilling machines. The findings show that for machine 001, the NPR increased from 71.39 $m^3$/hour in the first activity to 95.24 $m^3$/hour in the third activity. Similarly, for machine 002, the NPR rose from 53.49 $m^3$/hour in the second activity to 60.22 $m^3$/hour in the third activity. These improvements indicate that continuous adjustments and learning during operations can lead to better performance outcomes. However, the study also identifies several challenges that impact the drilling process. These challenges are categorized into avoidable and unavoidable obstacles. The data reveals a significant reduction in avoidable obstacles as the activities progress. For instance, avoidable obstacles for machine 001 decreased from 22.92 minutes per day in the first activity to 7.44 minutes per day in the third activity. This trend suggests that the frequency and impact of avoidable obstacles can be minimized through better management practices, training, and possibly more strategic planning. On the other hand, unavoidable obstacles, such as mechanical failures or adverse weather conditions, still pose a significant challenge. For machine 002, unavoidable obstacles remained relatively high, increasing to 50.98 minutes per day during the third activity. This highlights the need for companies to develop more robust contingency plans and maintain a high level of preparedness to address these unpredictable challenges.

Moreover, the study sheds light on the costs associated with drilling activities. It was found that the cost per meter of drilling varied across different activities and machines. For example, the actual drilling cost for machine 001 decreased from Rp 68,857 per meter in the first activity to Rp 58,873 per meter in the third activity. Conversely, for machine 002, the cost increased from Rp 81,324 per meter in the second activity to Rp 86,022 per meter in the third activity. These variations in cost can be attributed to factors such as fuel efficiency, maintenance needs, and the nature of the obstacles encountered. This underscores the importance of effective cost-management strategies in maintaining operational efficiency. The research provides several recommendations for improving drilling efficiency and effectiveness. It emphasizes the need for thorough planning of drilling activities, regular maintenance of equipment, and strategic management of resources. Ensuring that drilling machines and compressors are well-maintained and adequate spare parts are available can help minimize downtime and enhance productivity. Additionally, the study suggests further research into rocks' physical and mechanical properties and their impact on drilling speed and productivity. Understanding these geological factors more comprehensively could lead to more targeted and effective drilling strategies.

In conclusion, this research highlights that drilling productivity and efficiency at PT. Hansindo Mineral Persada is influenced by a complex interplay of factors, including drilling speed, operational challenges, and cost management. While unavoidable challenges need to be managed, there are also significant opportunities for improvement through better planning, training, and equipment management. By addressing these factors strategically, the company can enhance its drilling operations, reduce costs, and improve overall sustainability in the future. The insights gained from this study are valuable for developing more effective drilling strategies and improving the overall efficiency of drilling operations in the mining industry.

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## 6. Author's Note

We, the authors of the research article titled "Productivity and Cost Analysis of Drilling for Blast Holes in Granite Mining at PT. Hansindo Mineral Persada," affirm that this publication is free from any elements of plagiarism. We have made every effort to ensure the originality of the content presented in this study. Any similarities in theoretical frameworks, methodologies, or analytical techniques with existing research are coincidental and represent standard practices in the academic and research community.

Using established theories and methods is fundamental to advancing knowledge, and our work is built upon the solid foundation laid by previous scholars. We have duly cited all sources of information, theories, and analysis methods referenced in our study. These citations are acknowledged throughout the text and are comprehensively listed in the bibliography.

We fully recognize and respect the intellectual property rights of other researchers and have adhered to ethical standards in writing and presenting our findings. If any overlap with other studies is observed, it is not intentional but rather an indication of the shared scientific approach within the field. We trust that this article contributes to the ongoing academic dialogue and is a valuable resource for future research in mining engineering and operational efficiency.

## 7. References

Adebayo, B., Taiwo, B. O., AFENI, B. T., Raymond, A. O., & Faluyi, J. O. (2023). **Improvement Of Drill Bit-Button Performance and Efficiency During Drilling: An Application of LSTM Model to Nigeria Southwest Mines**. Journal of Mining and Environment, 14(4), 1121–1139.

Al-Shargabi, M., Davoodi, S., Wood, D. A., Al-Rubaii, M., Minaev, K. M., & Rukavishnikov, V. S. (2023). **Hole-Cleaning Performance in Non-Vertical Wellbores: A Review of Influences, Models, Drilling Fluid Types, and Real-Time Applications**. Geoenergy Science and Engineering, 212551.

Bala, A. (2021). **An Assessment of Drilling and Blasting Techniques at Granite Quarry of AFDIN Construction Company Limited, Katsina State, Nigeria**. International Journal of Environment and Geoinformatics, 8(4), 450–459.

Barakat, M., Abu El Ela, M., & Khalaf, F. (2021). **Integrating Risk Management Concepts into The Drilling Non-Productive Time**. Journal of Petroleum Exploration and Production, 11, 887-900.

Barosz, P., Gołda, G., & Kampa, A. (2020). **Efficiency Analysis of Manufacturing Line with Industrial Robots and Human Operators**. Applied Sciences, 10(8), 2862.

Bigio, S., & Sannikov, Y. (2021). **A Model of Credit, Money, Interest, and Prices (No. w28540)**. National Bureau of Economic Research.

Burnham, A., Gohlke, D., Rush, L., Stephens, T., Zhou, Y., Delucchi, M. A., ... & Boloor, M. (2021). **Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains (No. ANL/ESD-21/4)**. Argonne National Lab.(ANL), Argonne, IL (United States).

Careddu, N. (2020). **Chromaticism Differentiations: A Study of The Diversified Aesthetic Appeal of The Ghiandone Granite Range**. Journal of Building Engineering, p. 30, 101300.

Costa, F. P. D., Fernandes, J. V., Melo, L. R. L. D., Rodrigues, A. M., Menezes, R. R., & Neves, G. D. A. (2021). **The Potential for Natural Stones from Northeastern Brazil to Be Used in Civil Construction**. Minerals, 11(5), 440.

Dupriest, F., & Noynaert, S. (2022, March). Drilling practices and workflows for geothermal operations. In SPE/IADC Drilling Conference and Exhibition (p. D021S015R001). SPE.

Gooneratne, C. P., Magana-Mora, A., Otalvora, W. C., Affleck, M., Singh, P., Zhan, G. D., & Moellendick, T. E. (2020). **Drilling in the Fourth Industrial Revolution—Vision and Challenges**. IEEE Engineering Management Review, 48(4), 144–159.

Hanzlík, P., & Teplý, P. (2022). **Key Factors of the Net Interest Margin of European and US Banks in a Low Interest Rate Environment**. International Journal of Finance & Economics, 27(3), 2795-2818.

Islam, E. S., Vijayagopal, R., Moawad, A., Kim, N., Dupont, B., Nieto Prada, D., & Rousseau, A. (2021). **A Detailed Vehicle Modeling & Simulation Study Quantifying Energy Consumption and Cost Reduction of Advanced Vehicle Technologies Through 2050 (No. ANL/ESD-21/10)**. Argonne National Lab.(ANL), Argonne, IL (United States).

Johari, S., & Jha, K. N. (2020). **Impact of Work Motivation on Construction Labor Productivity**. Journal of management in engineering, 36(5), 04020052.

Kingslin, M. T. (2023). **Closed Loop Control System for Automated Drilling Operations**. i-Manager's Journal on Instrumentation & Control Engineering, 11(1).

Liu, Z., Song, J., Kubal, J., Susarla, N., Knehr, K. W., Islam, E., ... & Ahmed, S. (2021). **Comparing Total Cost of Ownership of Battery Electric Vehicles and Internal Combustion Engine Vehicles**. Energy Policy, 158, 112564.

Mathur, R. K., Macpherson, J., Krueger, S., & Goel, A. (2020, May). **A Step Change in Drilling Efficiency Using Remote Operations**. In Offshore Technology Conference (p. D011S007R002). OTC.

Naidu, P. T., Kumar, P., Ravi, V., Kumar, S. R. K. S. S. G., Krishna, D. V., & Ravi, B. (2020). **Case Study of Control Blasting in Granite Mines**. International Research Journal of Engineering and Technology, 7(5), 1–5.

Nikkhah, A., Vakylabad, A. B., Hassanzadeh, A., Niedoba, T., & Surowiak, A. (2022). **An Evaluation on the Impact of Ore Fragmented by Blasting on Mining Performance**. Minerals, 12(2), 258.

Pimenov, D. Y., Mia, M., Gupta, M. K., Machado, Á. R., Pintaude, G., Unune, D. R., ... & Kuntoğlu, M. (2022). **Resource Saving by Optimization and Machining Environments for Sustainable Manufacturing: A Review and Future Prospects**. Renewable and Sustainable Energy Reviews, 166, 112660.

Prodjosumarto, P. (1996). **Pemindahan Tanah Mekanis**. Jurusan Teknik Pertambangan, Institut Teknologi Bandung, Bandung

Samatemba, B., Zhang, L., & Besa, B. (2020). **Evaluating and Optimizing the Effectiveness of Mining Equipment; the Case of Chibuluma South Underground Mine**. Journal of Cleaner Production, 252, 119697.

Shcherbakov, P., Tymchenko, S., Bitimbayev, M., Sarybayev, N., & Moldabayev, S. (2021). **Mathematical Model to Optimize Drilling-and-Blasting Operations in the Process of Open-Pit Hard Rock Mining**. Mining of Mineral Deposits.

Sherafat, B., Ahn, C. R., Akhavian, R., Behzadan, A. H., Golparvar-Fard, M., Kim, H., ... & Azar, E. R. (2020). **Automated Methods for Activity Recognition of Construction Workers and Equipment: State-Of-The-Art Review**. Journal of Construction Engineering and Management, 146(6), 03120002.

Teodoriu, C., & Bello, O. (2021). **An Outlook of Drilling Technologies and Innovations: Present Status and Future Trends**. Energies, 14(15), 4499.

Warguła, Ł., Kukla, M., Krawiec, P., & Wieczorek, B. (2020). **Reduction in Operating Costs and Environmental Impact Consisting in the Modernization of the Low-Power Cylindrical Wood Chipper Power Unit by Using Alternative Fuel**. Energies, 13(11), 2995.

Wilopo, D. (2009). **Metode Konstruksi Dan Alat-alat Berat**. Jakarta: Penerbit Universitas Indobesia (UI-Press)

Wodecki, J., Góralczyk, M., Krot, P., Ziętek, B., Szrek, J., Worsa-Kozak, M., ... & Czajkowski, A. (2020). **Process Monitoring in Heavy Duty Drilling Rigs—Data Acquisition System and Cycle Identification Algorithms**. Energies, 13(24), 6748.

Wong, T. K. M., Man, S. S., & Chan, A. H. S. (2020). **Critical Factors for the Use or Non-Use of Personal Protective Equipment Amongst Construction Workers**. Safety Science, 126, 104663.