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Analysis of Decreased Limestone Production on the Effect of Rainfall with the Linear Regression Method

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ABSTRACT

Limestone mining is a quarry system mining. Its production is influenced by weather factors, especially rainfall. This study aimed at determining the mathematical model wich is able to correlate the influence of rainfall on production of limestone. In addition, it analyzed the correlation between rainfall and limestone production using linear regression method. There are four important steps in this research. The first step is to collect data production and production factors. The second step is to process the data into a mathematical model using linear regression. The third step is to test the result of the mathematical model with the statistical test method. Then the fourth step is to analyze the mathematical model that has met the statistical test results. The results showed that the best mathematical model was: Log P = 0.502 x LOG ((JO X Pr) $^{1.99}$ x (CH)$^{-0.001}$) + 0.0002. In conclusion, the effect of rainfall toward the production derivation was very low. Besides, operation hours and productivity also affected production derivation.

Keywords: *Limestone, Rainfall, Mathematical Models, Mining Production.*

1. INTRODUCTION

In general, the mining industry in Indonesia is open-pit mining [1]. Open-pit mining is a mining method that is directly exposed to free air because it is above the earth's surface [2]. Open-pit mining results in contamination in open spaces [3]. Therefore, weather factors greatly influence the productivity of open pit mines apart from work effectiveness and material hardness [4]. The research location is at the Limestone Quarry, one of the cement companies in Pangkajene and Islands Regency, South Sulawesi. The Kuari area has a tropical climate and consists of two seasons, namely the rainy season and the dry season [5].

This research focuses on finding the relationship between weather factors, rainfall and limestone production factors. So, we will find out the influence of rainfall on the decline in the value of limestone production. This influence will be analyzed using mathematical model analysis. Mathematical model analysis is an approach to studying the factors that influence the production value of limestone so that we can find out the extent of its influence on the decline in production value using the linear regression statistical method.

The linear regression method is a way to determine the relationship between the dependent (not independent) variable and the independent variable [6]. If these two variables are expressed in curve form, they will be straight lines. This method was created by trial and error, where the form of the equation obtained must be subjected to statistical tests which include the correlation coefficient (R), coefficient of determination (R^2), deviation factor (standard deviation), and level of convergence (C).

The results of this linear regression statistical method will be applicable if the results of the statistical tests carried out meet the requirements and expressed in curve form [7], then the plot points of the dependent variable and the independent variable will be collected and form a straight line. This is described in the high correlation coefficient, determination coefficient, convergence levels, and small standard deviation.

2. LITERATURE REVIEW

2.1 *Rainfall Analysis*

Rainfall is the amount of rain that occurs in an area [8]. Rainfall is a very important factor in planning a drainage system because the amount of rainfall in a mining area will influence the amount of mine water that must be handled [9]. The rainfall figures obtained are data that cannot be used directly for planning the creation of mine water control facilities but must be processed first to obtain more accurate rainfall values. Rainfall is the main data in planning open mine drainage activities [10].

Rainfall observations are carried out using a rain gauge [11]. There are two types of rainfall measuring instruments, namely manual and automatic measuring instruments. This tool is usually placed in an open area so that falling rainwater is not blocked by buildings or trees. This data is useful when determining planned rainfall. Analysis of rainfall data can be done using two methods: Annual series, namely by taking one maximum data each year, which means that only the maximum amount for each year is considered to be influential in data analysis. Partial Duration Series, namely by first determining a certain lower limit for rainfall, then data that is greater than this lower limit is taken and used as data to be analyzed.

Planned rain is the maximum rain that may occur during the planning life of the distribution [12]. To obtain rainfall for a certain rain return period and short-term rain intensity, it is necessary to carry out a rainfall analysis, in this case, the rainfall intensity of one hour.

2.2 *Linear Regression Method*

Three methods are used in the Linear Regression Method, namely Determining the Mathematical Model, Linear Regression Analysis, and Statistical Tests [13]. In determining the form of a mathematical model to determine limestone production targets, the influencing factors consist of Productivity (Pr), production time (T), and rainfall (C).

A way to study the relationship between production (P) and productivity (Pr), namely the total volume of material per unit time, operating hours (JO), rainfall (C), and number of working days (T), namely through the application of mathematical models. Production (P) is expressed as the dependent variable (Y). Productivity (Pr), operating hours (JO), rainfall (C), and number of working days (T) are expressed as independent variables (X). Testing is carried out by trial and error or trial and error.

To determine the level of validity of the relationship between the dependent variable (variable Y) and the independent variable (variable X), a statistical test is needed which includes the correlation coefficient (R) [14], coefficient of determination (F), standard deviation (SD) and level of convergence (C).

2.3 *Geological Condition of the Research Area*

The geomorphology of the research area is divided into 3 landscape units based on morphography, morphometry and morphogenesis approaches [15], namely the Karst landscape unit and the Fluvial landscape unit.

The research area is composed of carbonate sedimentary rocks in the form of limestone and alluvial deposits [16]. Based on the lithological characteristics, the naming, division, and determination of groups of rock units is based on informal lithostratigraphy, which is based on the uniformity of physical characteristics that can be observed in the field which includes rock type, rock dominance, uniformity of lithological characteristics, stratigraphic position and the relationship between one rock and another. other rocks that can be mapped on a scale of 1: 25,000, as well as stratigraphic relationships between rock units. In general, the stratigraphic sequence of this area is divided into limestone, clay, and river sediment (alluvial) units [17].

The regional geological structure of the research area according to Sukamto (1982) states that the end of volcanic activity in the Early Miocene was followed by tectonic activity which caused the beginning of the Walanae Terban. Terban Walanae extends from north to south of the Western Sulawesi Arm, where this fault structure influences the surrounding geological structure. This tectonic process also caused the formation of the basin where the Walanae Formation was formed. This event took place since the beginning of the Middle Miocene and decreased slowly during the sedimentation process until the Pliocene

2.4 Limestone Mining Activities

Pioneering is a series of work carried out to clean, level, and create a road for mechanical equipment to pass through, as well as provide a mining location to make it easier to collect material [18]. Pioneering work was carried out by the Mine Initiation and Planning Section using a bulldozer [19] and other tools. After the pilot work has been completed, the work is handed over to the Mining Section to continue production work [20].

Dismantling is a series of work carried out to free excavated materials from their parent deposits into fragments of the desired size [21]. The demolition activities carried out by the Company were by blasting the parent rock [22].

Loading is a series of activities or work carried out to pick up or load explosive material onto transportation equipment [23]. The loading equipment used is an excavator [24] with a bucket capacity of 2.1 m^3 and 2.2 m^3,And Then Transport activities are carried out to transport deposits of explosive material from the mining front to Crusher Unit. The transport equipment used is a dump truck with a capacity of 20-25 tonnes.

3. METHODS

The method used in this research is based on the linear regression method which is used to form a relationship model [25] between the dependent variable (dependent; response; Y) and one or more independent variables (independent, predictor, X). In simple terms, the stages in this research can be seen in Figure 1.

The method used in this research is based on a descriptive approach which aims to compare the reality in the field with the theory that the author obtained, as well as trying to create an alternative approach to solving it.

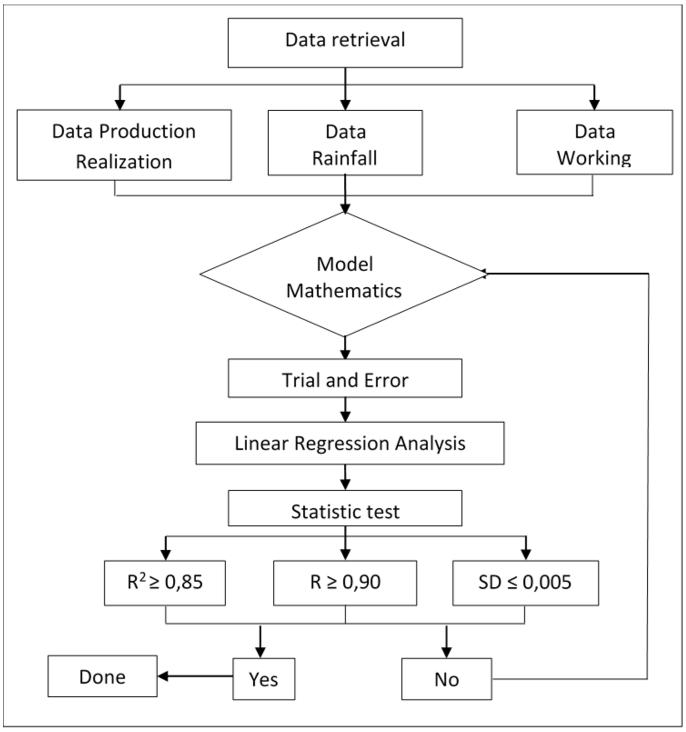

Figure 1. Research Stages

Production (P) is expressed as the dependent variable (Y). Working hours (JK), productivity (Pr), and rainfall (CH) are expressed as independent variables (X). Testing is carried out by trial and error or trial and error. The general form of this equation is expressed in the form of a linear equation Murray R. Spiegel & Larry J.Stephens, namely:

$$Y = aX + b$$

Where:
Y = Dependent variable (P)
X = Independent variables (Pr, JO, CH and T)
a and b = Constant

Constants a and b are calculated based on the equation

$$a = \frac{\left(\sum Y\right)\left(\sum X\right) - n\sum XY}{\left(\sum X\right)^2 - n\sum X^2}$$

$$b = \frac{\left(\sum Y\right)\left(\sum (X)^2\right) - \left(\sum XY\right)\left(\sum X\right)}{n\sum X^2 - \left(\sum X\right)^2}$$

To determine the level of validity of the relationship of the dependent variable (variable Y) with the independent variable (variable X), statistical tests are needed which include the correlation coefficient (R), coefficient of determination (F), standard deviation (SD) and convergence rate (C). The forms of equations to determine these four variables are as follows:

$$R = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}}$$

$F = R^2$

$$SD = \left|\frac{Y - Y^*}{Y}\right| x100\%$$

$Y^* = Yreg$

C = 100 – SD

4. RESULTS AND DISCUSSION

Based on the research results with the data above through a linear regression process, mathematical models were obtained for the influence of Operating Hours (JO), Productivity (Pr), Number of Working Days (T) and Rainfall (C) on Production Results (P) that is:

• 1st Mathematical Model:
$\text{Log } P = 0{,}835 \times \text{LOG}((\text{Pr XJO })^{1,2} \times (CH)^{-0,01})] + 0{,}005$
• 2nd Mathematical Model:
$\text{Log } P = 1{,}0003 \times \text{LOG}((\text{Pr X JO}) \times (CH)^{-0,001}) + 0{,}0004$
• 3rd Mathematical Model:
$\text{Log } P = 0{,}502 \times \text{LOG}((\text{Pr X JO })^{1,99} \times (CH)^{-0,001})] + 0{,}0002$

Where:
P = Production, tons
Pr = Equipment Productivity, tons/hour
JO = Operating Hours
CH = Rainfall, mm

The three mathematical models above meet the requirements of statistical test results which include correlation coefficient (R), constant of determination (R), standard deviation (SD) and convergence level (C). Table 1, Figure 2, Figure 3, and Figure 4, are the results of data processing with linear regression.

Table 1. Statistical Test Results of Mathematical Models

Mathematical Model	R	R^2	SD (%)	sd	C
1st Mathematical Model	0,9997	0,9998	0,025	0,000	99,974
2nd Mathematical Model	0,9999	0,9999	0,003	0,000	99,997
3rd Mathematical Model	0,9999	0,9999	0,001	0,000	99,998

1. The 1st mathematical model shows that production (P) has a dependent variable that is positively correlated with the independent variable but is also influenced by other factors regarding Operating Hours (JO), Equipment Productivity (Pr) and Rainfall (CH). This is indicated by the R value between 0 and 1.00 and is positive.

2. The 2nd and 3rd mathematical models show that production (P) has a dependent variable and the independent variable has a strong and direct relationship or perfect positive correlation to Operating Hours (JO), Equipment Productivity (Pr) and Rainfall (CH). This is indicated by the R value equal to 0.999 and positive.
3. The 1st mathematical model has an average coefficient of determination (R) value of 0.999, which means that not the entire P value is influenced by Operating Hours (JO), Equipment Productivity (Pr) and Rainfall, there are still other factors that influence the P value
4. The 2nd and 3rd mathematical models have almost the same statistical test results, only the difference is in the standard deviation where the 3rd mathematical model has a smaller standard deviation than the standard deviation of the 2nd mathematical model.
5. The 2nd and 3rd mathematical models have coefficient of determination values (R) averages 0.999, which means that 99.99% of the P value is influenced by Operating Hours (JO), Equipment Productivity (Pr) and Rainfall.
6. When viewed from the standard deviation value, the best form of mathematical model to be applied in planning production targets is the 3rd mathematical model. This is because the 3rd mathematical model has the smallest standard deviation value, namely 0.001%. This means that it has the highest validity compared to other mathematical models. This is also supported by the convergence rate (C) which reached 99.99%.
7. Mathematical models 1, 2, and 3 can all be used as alternatives for planning production targets. This is because the three mathematical models have a high level of convergence (C), reaching above 99%. However, the third mathematical model really meets the requirements.

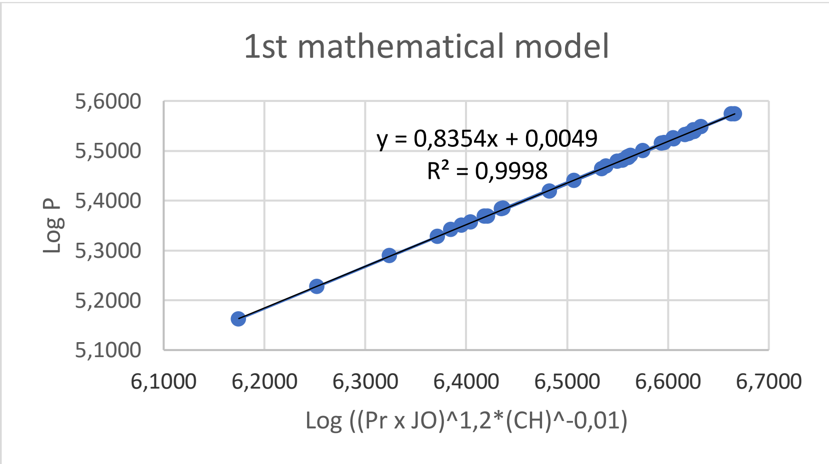

Figure 2. Linear Curve Equation 1

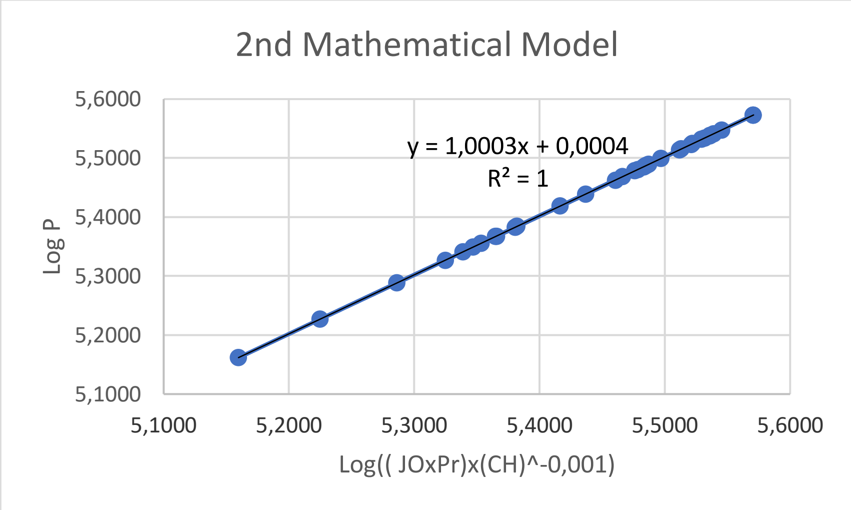

Figure 3. Linear Curve Equation 2

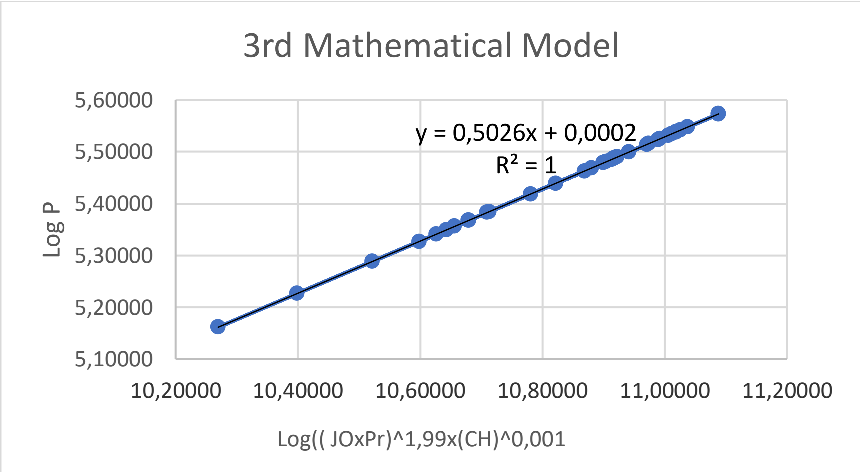

Figure 4. Linear Curve Equation 3

Based on the results of statistical test analysis regarding the relationship between the independent variable and the dependent variable, the independent variable is Rainfall (CH), Productivity (Pr), and Operating Hours (JO), while the dependent variable is Production (P), the appropriate mathematical model for analysis is:

3rd Mathematical Model:

$\text{Log P} = 0{,}502 \times \text{LOG}((\text{JO X Pr})^{1{,}99} \times (\text{CH})^{-0{,}001}) + 0{,}0002$

Because the standard deviation values, coefficient of determination, positive correlation and convergence level meet the requirements of the mathematical model to be analyzed.

The influence of production factors (JO, Pr, and CH) on P can be determined by substituting production factors into the mathematical model. The operating hours (JO) value is 193 hours/month and the productivity value (Pr) is 1,500 tons/month, which is the average value for the 2014-2016 period. Meanwhile, rainfall data (CH) uses planned rainfall data.

From the results of the analysis using a mathematical model it was found that the highest rainfall (CH) was = 272.80 mm with JO and Pr still producing production of = 289,858 tons/month, while for rainfall (CH) = 0 with JO and Pr still producing production was = 291,013 tons/month (table 4.2). From the production results, it can be seen that there is a reduction caused by increases and decreases in rainfall. The results of the mathematical model analysis can be seen in Table 4.2:

Table 2. Regression Equation Analysis

Month	JO	Pr	CH	Log P	P (ton)
x	193	1.500	0	5,463913	291.013
1	193	1.500	270,77	5,462187	289.859
2	193	1.500	236,27	5,462217	289.879
3	193	1.500	272,80	5,462186	289.858
4	193	1.500	191,23	5,462263	289.910
5	193	1.500	98,38	5,462408	290.007
6	193	1.500	255,73	5,4622	289.868
7	193	1.500	119,24	5,462366	289.979
8	193	1.500	87,86	5,462433	290.023
9	193	1.500	163,06	5,462298	289.933
10	193	1.500	98,58	5,462408	290.007
11	193	1.500	134,75	5,46234	289.961
12	193	1.500	262,04	5,462195	289.864

Table 4.2 shows the overall results of the analysis of various rainfall conditions (CH), showing a decrease in production output (P) per month which is caused by the influence of operating hours (JO), productivity (Pr), and rainfall (CH). The decline in production reached = 20 tons to = 139 tons per month.

5. CONCLUSION

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. Based on the results of statistical test analysis regarding the relationship between the independent variables and the dependent variable, where the independent variables are Rainfall (CH), Productivity (Pr), and Operating Hours (JO), while the dependent variable is Production (P), the best mathematical model is:

   $$\text{Log P} = 0{,}502 \text{ x LOG}((\text{JO X Pr})^{1{,}99} \text{ x } (\text{CH})^{-0{,}001}) + 0{,}0002$$

   Because it has the smallest standard deviation value, namely 0.001%. This means that it has the highest validity compared to other mathematical models. This is also supported by the convergence level (C) which reached 99.998%.

2. The analysis results show that rainfall (CH) has a direct and mathematical effect on decreasing production, by adding operating hours (JO) and equipment productivity (Pr) into the mathematical model equation, but the effect of rainfall is very low on reducing limestone production.

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REFERENCES

[1] R. Juniah, R. Dalimi, M. Suparmoko, S. S. Moersidik, and H. Waristian, "Environmental value losses as impacts of natural resources utilization of in coal open mining," *MATEC Web Conf.*, vol. 101, pp. 4–8, 2017, doi: 10.1051/matecconf/201710104013.

[2] Hidayat and Syamsul, "Environmental Impacts of Open Pit Mining Blasting: Particular Discussions on Some Specific Issues," *J. Min. Environ. Technol.*, vol. 1, no. 1, pp. 1–11, 2021, [Online]. Available: http://journal.ummat.ac.id/index.php/JMET

[3] F. Bianchini *et al.*, "Elemental contamination of an open-pit mining area in the Peruvian Andes," *Int. J. Environ. Sci. Technol.*, vol. 12, no. 3, pp. 1065–1074, 2015, doi: 10.1007/s13762-013-0493-8.

[4] B. Chenari, J. Dias Carrilho, and M. Gameiro Da Silva, "Towards sustainable, energy-efficient and healthy ventilation strategies in buildings: A review," *Renew. Sustain. Energy Rev.*, vol. 59, pp. 1426–1447, Jun. 2016, doi: 10.1016/J.RSER.2016.01.074.

[5] D. P. Ariyanto, R. P. W. Priswita, Komariah, Sumani, and M. Senge, "Determining the wet season onset toward crop water availability under the tropical monsoon climate," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 200, no. 1, 2018, doi: 10.1088/1755-1315/200/1/012010.

[6] G. K. Uyanık and N. Güler, "A Study on Multiple Linear Regression Analysis," *Procedia - Soc. Behav. Sci.*, vol. 106, pp. 234–240, Dec. 2013, doi: 10.1016/J.SBSPRO.2013.12.027.

[7] M. A. Pourhoseingholi, A. R. Baghestani, and M. Vahedi, "How to control confounding effects by statistical analysis," *Gastroenterol. Hepatol. from Bed to Bench*, vol. 5, no. 2, pp. 79–83, 2012.

[8] M. Basinger, F. Montalto, and U. Lall, "A rainwater harvesting system reliability model based on nonparametric stochastic rainfall generator," *J. Hydrol.*, vol. 392, no. 3–4, pp. 105–118, Oct. 2010, doi: 10.1016/J.JHYDROL.2010.07.039.

[9] C. M. Côte, C. J. Moran, C. J. Hedemann, and C. Koch, "Systems modelling for effective mine water management," *Environ. Model. Softw.*, vol. 25, no. 12, pp. 1664–1671, Dec. 2010, doi: 10.1016/J.ENVSOFT.2010.06.012.

[10] T. A. Cahyadi, S. Magdalena, D. Haryanto, W. D. Ratminah, P. E. Rosadi, and P. E. Asmara, "Planning of mining water management costs," *AIP Conf. Proc.*, vol. 2245, no. 1, p. 90008, Jul. 2020, doi: 10.1063/5.0007076.

[11] A. Gires, I. Tchiguirinskaia, D. Schertzer, A. Schellart, A. Berne, and S. Lovejoy, "Influence of small scale rainfall variability on standard comparison tools between radar and rain gauge data," *Atmos. Res.*, vol. 138, pp. 125–138, Mar. 2014, doi: 10.1016/J.ATMOSRES.2013.11.008.

[12] A. L. A. Martins, G. R. Liska, L. A. Beijo, F. S. de Menezes, and M. Â. Cirillo, "Generalized Pareto distribution applied to the analysis of maximum rainfall events in Uruguaiana, RS, Brazil," *SN Appl. Sci.*, vol. 2, no. 9, p. 1479, 2020, doi: 10.1007/s42452-020-03199-8.

[13] S. Li and X. Yuan, "Application of Linear Regression Mathematical Model in the Evaluation of Teachers' Informatization Quality," *Complexity*, vol. 2021, 2021, doi: 10.1155/2021/5599655.

[14] G. Anggadwita and Q. Y. Mustafid, "Identification of Factors Influencing the Performance of Small Medium Enterprises (SMEs)," *Procedia - Soc. Behav. Sci.*, vol. 115, pp. 415–423, Feb. 2014, doi: 10.1016/J.SBSPRO.2014.02.448.

[15] M. Gustavsson, E. Kolstrup, and A. C. Seijmonsbergen, "A new symbol-and-GIS based detailed geomorphological mapping system: Renewal of a scientific discipline for understanding landscape development," *Geomorphology*, vol. 77, no. 1–2, pp. 90–111, Jul. 2006, doi: 10.1016/J.GEOMORPH.2006.01.026.

[16] R. D. P. Astuti *et al.*, "Health risks from multiroute exposure of potentially toxic elements in a coastal community: a probabilistic risk approach in Pangkep Regency, Indonesia," *Geomatics, Nat. Hazards Risk*, vol. 13, no. 1, pp. 705–735, 2022, doi: 10.1080/19475705.2022.2041110.

[17] A. Brumm *et al.*, "A reassessment of the early archaeological record at Leang Burung 2, a Late Pleistocene rock-shelter site on the Indonesian island of Sulawesi," *PLoS One*, vol. 13, no. 4, p. e0193025, Apr. 2018, [Online]. Available: https://doi.org/10.1371/journal.pone.0193025

[18] J. A. Aznar-Sánchez, J. F. Velasco-Muñoz, L. J. Belmonte-Ureña, and F. Manzano-Agugliaro, "Innovation and technology for sustainable mining activity: A worldwide research assessment," *J. Clean. Prod.*, vol. 221, pp. 38–54, Jun. 2019, doi: 10.1016/J.JCLEPRO.2019.02.243.

[19] M. Hirayama, J. Guivant, J. Katupitiya, and M. Whitty, "Path planning for autonomous bulldozers," *Mechatronics*, vol. 58, pp. 20–38, Apr. 2019, doi: 10.1016/J.MECHATRONICS.2019.01.001.

[20] L. Dong, X. Tong, X. Li, J. Zhou, S. Wang, and B. Liu, "Some developments and new insights of environmental problems and deep mining strategy for cleaner production in mines," *J. Clean. Prod.*, vol. 210, pp. 1562–1578, Feb. 2019, doi: 10.1016/J.JCLEPRO.2018.10.291.

[21] Muhammad Zaki Fatlut Rahman, "Calculation of The Cost of Underground Mining Activities on Tunnel 9 PT. Allied Indo Coal Jaya," *Georest*, vol. 1, no. 1, pp. 13–16, 2022, doi: 10.57265/georest.v1i1.4.

[22] L. J. Drew, W. H. Langer, and J. S. Sachs, "Environmentalism and Natural Aggregate Mining," *Nat. Resour. Res.*, vol. 11, no. 1, pp. 19–28, 2002, doi: 10.1023/A:1014283519471.

[23] K. Awuah-Offei, "Energy efficiency in mining: a review with emphasis on the role of operators in loading and hauling operations," *J. Clean. Prod.*, vol. 117, pp. 89–97, Mar. 2016, doi: 10.1016/J.JCLEPRO.2016.01.035.

[24] A. V. Mikhailov, A. I. Zhigulskaya, and T. B. Yakonovskaya, "Excavating and loading equipment for peat mining," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 87, no. 2, 2017, doi: 10.1088/1755-1315/87/2/022014.

[25] S. D. Permai and H. Tanty, "Linear regression model using bayesian approach for energy performance of residential building," *Procedia Comput. Sci.*, vol. 135, pp. 671–677, Jan. 2018, doi: 10.1016/J.PROCS.2018.08.219.

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