Selection of Most Proper Blasting using TOPSIS Method in PT Pamapersada Nusantara Jobsite TOPB

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Abstract. Blasting is an important operation in mining. The improper selection of blasting geometry will create a problem with blasting results, such as rock fragmentation with a lot of boulders, flyrock, high ground vibrations, high air blasts, long digging time, and high powder factor values. Based on the problems that arise, choosing the right blasting geometry will certainly be needed. Selecting the right blasting geometry can be done using the Multi Criteria Decision Making (MCDM). TOPSIS is one method that can be used in decision making. In determining the right geometry using this TOPSIS, safety and technical parameters are taken into consideration. Finally, blasting geometry with burden of 6.5 m, spacing of 7.5 m, drill hole diameter of 20 cm, subdrilling of 0.5 m, hole depth of 7.25 m and stemming of 4.3 m has been presented as the most suitable blasting geometry for PT Pamapersada Nusantara Jobsite TOPB.

1. Introduction
Blasting on overburden removal carried out at PT Pamapersada Nusantara Jobsite TOPB is still said to be unsatisfactory, this can be seen from the blasting success parameters (fragmentation, digging time, powder factor, flyrock, ground vibration and air blast) that have not met the standards. Based on the observations that have been made, of the six parameters of successful blasting there are four parameters that do not meet the standards, including fragmentation, digging time, powder factor and flyrock.

Therefore, based on the problems described above it is necessary to evaluate the results of blasting. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is a type of Multi Criteria Decision Making (MCDM) that can be used in evaluating blasting results, where the TOPSIS method is able to determine the best alternative from a number of alternatives based on certain criteria. The results of this study are expected to be able to provide information on the extent of the successful blasting carried out by PT Pamapersada Nusantara Jobsite TOPB, so that the company can determine the appropriate blasting geometry to use.
2. Literature Review

2.1. Blasting
Blasting is one method that can be used for material demolition [1]. Based on [2] Blasting in mining activities, in addition to cleaning rocks (fragmentation) will also cause seismic wave propagation that describes energy travel through the earth and results in vibrations in the mass of rocks or surrounding material.

2.2. Factors Affecting Blasting Results

2.2.1. Achievement of Production Targets. Blasting is one of the important factors in determining the success of production obtained in mining activities [3]. Therefore the achievement of production targets is an important indicator in determining the success of a blasting activity in a company.

2.2.2. Efficiency of Explosives. According to [4] in each blasting the size of the fragmentation requires the width of the crusher opening and the lowest possible powder factor (PF). Based on [5] fragmentation is closely related to the comparison of the contents of explosives against exposed rock (powder factor), which are applied in the form of blasting geometry. The smaller the percentage of boulder material targeted, the greater the use of filling in explosives.

2.2.3. Fragmentation. Fragmentation is a general term used to indicate the size of each blast resulting from blasting. According to [6] fragmentation refers to the size distribution of rocks obtained after blasting activities. The indicator of the success of blasting in addition to achieving the target of blasting production is fragmentation [7]. Blasting can be said to be successful, that is, if the fragmentation with the resulting chunks is <15%, this is also in line with the provisions of the company that set the maximum extent of fragmentation of rocks with a size of > 100 cm is 15%.

2.2.4. Digging Time. Digging time is the time needed by the loading excavator to load material into the bucket. The rock fragmentation resulting from blasting which has a lot of boulder will make the digging time value large. The amount of digging time will affect the cycle time of the digging tool, so that it will have a negative impact on blasting rock production.

2.2.5. Safe Conditions. Based on [8] blasting activities aimed at separating rocks from their parents in the mining industry are very vulnerable to danger. The indicators that are seen in a safe condition during this blasting activity are not using safety, smoking in the relaxation area, tools or humans at an insecure distance, using electronic devices in the blasting area and misfire.

2.2.6. Impact on the Environment (Flyrock, Toxic Gas, Ground Vibration & Air Blast). Flyrock is a general term used to refer to flying stones that appear in blasting activities. According to [9] Nitrogen oxide smoke is easily identified as the post-explosion yellow cloud produced. The white gas is thought to be mist from water vapor (H2O) which also indicates too much water in the explosive hole, while the blackish-colored gas appears as a result of incomplete combustion. Blasting vibrations are vibrations caused by blasting activities in open-pit mining, while air blasts are energy released by blasting which causes overpressure expressed in pounds per square (psi), decibel (dB) and pascal (Pa) The blasting noise level is 110 dB and may only be exposed to a maximum of 0.5 hours/day [10].

2.3. Multi-Criteria Decision Making Method (MCDM)
Multi-criteria decision making is a method used for evaluation, prioritization and selection of the best available alternatives. Multi Criteria Decision Making is a method of decision making to determine the best alternative from a number of alternatives based on certain criteria. Multi criteria decision making is one of the best ways in decision making [11]. According to [12] the selection of the best blasting patterns from several alternatives available for use in the Sungun Copper Mine can be done using a
linear assignment method, whereas according to [13] Optimization Demand Measurement (ODM) can help engineers carry out blasting designs in order to optimize blasting operations under different mining conditions and ODM can also assist in actual evaluation of blasting results. Based on [14] a quantitative method that can be used appropriately in evaluating the results of blasting and determining the blast pattern, so that the existence of this method is able to control and optimize the operating cycle of open pit mining.

2.4. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
TOPSIS is one of the multicriteria or alternative choice decision making methods that is an alternative that has the smallest distance from positive ideal solutions and the largest distance from negative ideal solutions from a geometric point of view using Euclidean distance, but alternatives that have the smallest distance from positive ideal solutions, no must have the greatest distance from the negative ideal solution. TOPSIS is the most applicable method for MADM to evaluate and determine the best blasting pattern [15].

3. Data Analysis Technique
The data analysis technique carried out in this study was using Multi-Criteria Decision Making (MCDM), which is Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The steps that must be taken in using the TOPSIS method are as follows:

3.1. Building A Decision Matrix
X decision matrix refers to alternative m which will be evaluated based on n criteria. In this study there were twenty alternatives available with six criteria, namely powder factor, flyrock, ground vibration, air blast, digging time and fragmentation.

3.2. Making A Normalized Decision Matrix
A element \( r_{ij} \) of the normalized decision matrix is calculated as follows.

\[
r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}}
\]

3.3. Creating A Weighted Normalized Decision Matrix
The weighted normalized decision matrix is made by multiplying the weight \( w_i \) with \( r_{ij} \). The number of weights for the six criteria you have is 1.

3.4. Determining The Ideal Positive Solution Matrix and Ideal Negative Solution
The positive ideal solution or symbolized by \( A^* \) is the maximum value of each criterion in twenty available alternatives, while the ideal negative solution or symbolized by \( A^- \) is the minimum value of each criterion in twenty available alternatives.

\[
A^* = \left\{ \left( \max_i v_{ij} \right) \left| j \in J \right\} , \left( \min_i v_{ij} \right) \left| j \in J \right\} , i = 1,2,3,\ldots,m \right\} = \{v_1^*, v_2^*, \ldots, v_n^*\}
\]

\[
A^- = \left\{ \left( \min_i v_{ij} \right) \left| j \in J \right\} , \left( \max_i v_{ij} \right) \left| j \in J \right\} , i = 1,2,3,\ldots,m \right\} = \{v_1^-, v_2^-, \ldots, v_n^-\}
\]

3.5. Calculating The Size of Separation
There are two types of separations, namely positive separation \( S_{i^*} \) and negative separation \( S_{i^-} \).
The blasting geometry can be seen in Table 1 below.

| Pattern | D (cm) | B (m) | S (m) | J (m) | H (m) | Stemm (m) |
|---------|--------|-------|-------|-------|-------|-----------|
| P 1     | 20     | 7     | 8     | 0.5   | 7.5   | 4         |
| P 2     | 20     | 7     | 8     | 0.5   | 6.5   | 3.7       |
| P 3     | 20     | 6.83  | 7.83  | 0.5   | 6.33  | 3.8       |
| P 4     | 20     | 7     | 8     | 0.5   | 7.5   | 4.4       |
| P 5     | 20     | 7     | 8     | 0.25  | 6.15  | 3.1       |
| P 6     | 20     | 7     | 8     | 0.5   | 7.5   | 4         |
| P 7     | 20     | 7     | 8     | 0.5   | 6.5   | 3.2       |
| P 8     | 20     | 7     | 8     | 0.5   | 7     | 8         |
| P 9     | 20     | 7     | 8     | 0.5   | 6.5   | 3.7       |
| P 10    | 20     | 7     | 8     | 0.5   | 7     | 3.9       |
| P 11    | 20     | 6.5   | 7.5   | 0.5   | 5     | 3         |
| P 12    | 20     | 7     | 8     | 0.5   | 7.5   | 4.5       |
| P 13    | 20     | 7     | 8     | 0.5   | 6.5   | 3.2       |
| P 14    | 20     | 7     | 8     | 0.5   | 7.5   | 4.5       |
| P 15    | 20     | 6.67  | 7.67  | 0.5   | 6.33  | 3.5       |
| P 16    | 20     | 7     | 8     | 0.5   | 7.5   | 4.5       |
| P 17    | 20     | 7     | 8     | 0.5   | 6.5   | 3.2       |
| P 18    | 20     | 6.5   | 7.5   | 0.5   | 7.25  | 4.3       |
| P 19    | 20     | 7     | 8     | 0.5   | 6.5   | 3.7       |
| P 20    | 20     | 7     | 8     | 0.5   | 7     | 3.9       |

4.1. Description of Data
The blasting geometry applied by the company when the authors make measurements for twenty blasting times has different values. The blasting geometry can be seen in Table 1 below.

### Table 1. Applied blasting geometry.

4.2. Data Analysis

4.2.1. Building A Decision Matrix. In this study there were twenty alternatives available with six criteria, namely powder factor, flyrock, ground vibration, air blast, digging time and fragmentation. The X decision matrix can be seen in Table 2 below.

### Table 2. Decision matrix.

| Blast No | PF  | Fl  | GV  | AB  | DT  | Fr  | Blast No | PF  | Fl  | GV  | AB  | DT  | Fr  |
|----------|-----|-----|-----|-----|-----|-----|----------|-----|-----|-----|-----|-----|-----|
| 1        | 0.19| 20  | 3.85| 71  | 40  | 12.47| 0        | 11  | 0.17| 95  | 1.26| 85.40| 11.00| 0 |
| 2        | 0.20| 25  | 1.67| 65  | 80  | 12.33| 5.69     | 12  | 0.19| 55  | 3.23| 77.40| 11.96| 0 |
| 3        | 0.20| 35  | 2.61| 69  | 20  | 9.14 | 0        | 13  | 0.17| 107 | 3.36| 72.60| 10.45| 25.8 |
| 4        | 0.19| 45  | 2.47| 69  | 10  | 14.93| 0        | 14  | 0.15| 65  | 6.46| 62.20| 10.60| 5.75 |
| 5        | 0.19| 47  | 2.62| 57  | 80  | 9.91 | 0        | 15  | 0.23| 200 | 3.43| 79.60| 10.19| 0 |
| 6        | 0.22| 43  | 3.34| 79  | 60  | 11.01| 32.15    | 16  | 0.18| 25  | 3.25| 74.50| 10.09| 1.52 |
| 7        | 0.18| 50  | 4.07| 70  | 0.00| 11.00| 0        | 17  | 0.19| 30  | 2.92| 76.60| 10.91| 13.88 |
| 8        | 0.20| 105 | 5.48| 64  | 10  | 10.12| 0        | 18  | 0.19| 50  | 1.62| 59.40| 10.56| 0 |
| 9        | 0.20| 102 | 2.62| 69  | 30  | 11.32| 0.96     | 19  | 0.25| 75  | 0.9 | 67.10| 11.00| 23.53 |
| 10       | 0.16| 53  | 2.83| 67  | 90  | 10.70| 0        | 20  | 0.19| 0   | 3.24| 59.60| 11.00| 3.59 |

Information:
PF (Powder Factor: kg/m³), Fl (Flyrock: m), GV (Ground Vibration: mm/s), AB (Air Blast: dB), DT (Digging Time: second), Fr (Fragmentation: %).
4.2.2. Making A Normalized Decision Matrix. Normalized decision matrices can be calculated using predetermined equations. The results of the normalized decision matrix can be seen in Table 3 below.

Table 3. Normalized decision matrix.

|  | 1  | 2  | 3  | 4  | 5  | 6 |
|---|---|----|----|----|----|---|
| 1 | 0.2255 | 0.0596 | 0.4597 | 0.227 | 0.351 | 0.258 |
| 2 | 0.2376 | 0.0746 | 0.1126 | 0.209 | 0.248 | 0.113 |
| 3 | 0.2281 | 0.1044 | 0.176 | 0.22 | 0.184 | 0.035 |
| 4 | 0.2203 | 0.1342 | 0.1666 | 0.22 | 0.300 | 0.018 |
| 5 | 0.2189 | 0.1402 | 0.1767 | 0.164 | 0.199 | 0.025 |
| 6 | 0.2503 | 0.1282 | 0.2253 | 0.253 | 0.221 | 0.639 |

4.2.3. Creating A Weighted Normalized Decision Matrix. The weighted normalized decision matrix is made by multiplying the weight (w) with r_i. The results of the weighted normalized decision matrix can be seen in Table 4.

Table 4. Weighted normalized decision matrix.

| Blast No | PF | Fl | GV | AB | DT | Fr |
|---|---|----|----|----|----|---|
| 1 | 0.0371 | 0.0099 | 0.0433 | 0.0378 | 0.0419 | 0 |
| 2 | 0.0396 | 0.0124 | 0.0188 | 0.0349 | 0.0414 | 0.0189 |
| 3 | 0.0380 | 0.0174 | 0.2923 | 0.0367 | 0.0307 | 0 |
| 4 | 0.0367 | 0.0224 | 0.0278 | 0.0366 | 0.0501 | 0 |
| 5 | 0.0365 | 0.0234 | 0.2925 | 0.0306 | 0.0333 | 0 |
| 6 | 0.0417 | 0.0214 | 0.0375 | 0.0422 | 0.0370 | 0.1066 |
| 7 | 0.0352 | 0.0249 | 0.0457 | 0.0371 | 0.0369 | 0 |
| 8 | 0.0393 | 0.0522 | 0.0616 | 0.0340 | 0.0340 | 0 |
| 9 | 0.0385 | 0.0507 | 0.0295 | 0.0367 | 0.0380 | 0.0032 |
| 10 | 0.0307 | 0.0263 | 0.0318 | 0.0360 | 0.0359 | 0 |

4.2.4. Determining The Ideal Positive Solution Matrix and Ideal Negative Solution. The results of the matrix of positive and negative ideal solutions can be seen in Table 5 below.

Table 5. Ideal positive solution and ideal negative solution.

| Blast No | PF | Fl | GV | AB | DT | Fr |
|---|---|----|----|----|----|---|
| 1 | 0.0371 | 0.0099 | 0.0433 | 0.0378 | 0.0419 | 0 |
| 2 | 0.0396 | 0.0124 | 0.0188 | 0.0349 | 0.0414 | 0.0189 |
| 3 | 0.0380 | 0.0174 | 0.2923 | 0.0367 | 0.0307 | 0 |
| 4 | 0.0367 | 0.0224 | 0.0278 | 0.0366 | 0.0501 | 0 |
| 5 | 0.0365 | 0.0234 | 0.2925 | 0.0306 | 0.0333 | 0 |
| 6 | 0.0417 | 0.0214 | 0.0375 | 0.0422 | 0.0370 | 0.1066 |
| 7 | 0.0352 | 0.0249 | 0.0457 | 0.0371 | 0.0369 | 0 |
| 8 | 0.0393 | 0.0522 | 0.0616 | 0.0340 | 0.0340 | 0 |
| 9 | 0.0385 | 0.0507 | 0.0295 | 0.0367 | 0.0380 | 0.0032 |
| 10 | 0.0307 | 0.0263 | 0.0318 | 0.0360 | 0.0359 | 0 |

4.2.5. Calculating Separation. The values of positive and negative separations can be seen in Table 6 below.

Table 6. Positive separation value (S_i+) & negative separation value (S_i-).

| Blast No | Si+ | Blast No | Si+ | Blast No | Si- | Blast No | Si- |
|---|----|----|----|----|----|----|----|
| 1 | 0.14306 | 11 | 0.13388 | 1 | 0.0378 | 11 | 0.0500 |
| 2 | 0.1357 | 12 | 0.13467 | 2 | 0.0285 | 12 | 0.0408 |
| 3 | 0.14321 | 13 | 0.0657 | 3 | 0.0278 | 13 | 0.1049 |
| 4 | 0.13968 | 14 | 0.11337 | 4 | 0.0357 | 14 | 0.0731 |
| 5 | 0.14013 | 15 | 0.11314 | 5 | 0.0311 | 15 | 0.1051 |
| 6 | 0.06864 | 16 | 0.14025 | 6 | 0.1135 | 16 | 0.0314 |
| 7 | 0.13433 | 17 | 0.11271 | 7 | 0.0447 | 17 | 0.0552 |
| 8 | 0.11906 | 18 | 0.14287 | 8 | 0.0741 | 18 | 0.0274 |
| 9 | 0.12344 | 19 | 0.09408 | 9 | 0.0559 | 19 | 0.0887 |
| 10 | 0.13766 | 20 | 0.14367 | 10 | 0.0349 | 20 | 0.0304 |
4.2.6. Calculating The Proximity to Ideal Positive Solutions. The results of the $C_i^*$ calculation for the twenty available alternatives can be seen in Table 7 below.

Table 7. $C_i^*$ value for each alternative.

| Blast No | $C_i^*$  |
|----------|----------|
| 1        | 0.208934 |
| 2        | 0.17361  |
| 3        | 0.162767 |
| 4        | 0.203419 |
| 5        | 0.181838 |

4.2.7. Sort $C_i^*$ Value. The sequence of $C_i^*$ values from the smallest to the largest can be seen in Table 8 below.

Table 8. Sort $C_i^*$ value.

| Blast No | $C_i^*$ | Rank |
|----------|---------|------|
| 1        | 0.2089  | 9    |
| 2        | 0.1736  | 3    |
| 3        | 0.1627  | 2    |
| 4        | 0.2034  | 8    |
| 5        | 0.1818  | 5    |

5. Conclusion
Based on the results of this study, it can be concluded that, using the TOPSIS method, the 18th geometry pattern with a diameter of a drill hole of 20 cm, a burden of 6.5 meters, a space of 7.5 meters, a subdrill of 0.5 meters, a depth of 7.25 meters and 4.3 meter stemming is the most appropriate geometry to be used by Pamapersada Nusantara Jobsite TOPB in blasting activities.

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