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SELECTION OF MOST PROPER BLASTING PATTERN IN MINES USING LINEAR ASSIGNMENT METHOD: SUNGUN COPPER MINE

WYBÓR NAJODPOWIEDNIEJSZEGO SCHEMATU PROWADZENIA PRAC STRZAŁOWYCH W KOPALNI MIEDZI SUNGUN Z UŻYCIEM METODY PRZYPORZĄDKOWANIA LINIOWEGO

One of the most important operations in mining is blasting. Improper design of blasting pattern will cause technical and safety problems. Considering impact of results of blasting on next steps of mining, correct pattern selection needs a great cautiousness. In selecting of blasting pattern, technical, economical and safety aspects should be considered. Thus, most appropriate pattern selection can be defined as a Multi Attribute Decision Making (MADM) problem.

Linear assignment method is one of the very applicable methods in decision making problems. In this paper, this method was used for the first time to evaluate blasting patterns in mine. In this ranking, safety and technical parameters have been considered to evaluate blasting patterns. Finally, blasting pattern with burden of 3.5 m, spacing of 4.5 m, stemming of 3.8 m and hole length of 12.1 m has been presented as the most suitable pattern obtained from linear assignment model for Sungun Copper Mine.

Keywords: Blasting Pattern, Multi Attribute Decision Making (MADM) Models, linear assignment method, Case Study, Sungun Copper Mine

Jedną z najpoważniejszych operacji wykonywanych w ramach prac wydobywczych są prace strzałowe. Niewłaściwe rozplanowanie prac powoduje problemy techniczne i stanowi zagrożenie dla bezpieczeństwa. Z uwagi na potencjalne skutki prac strzałowych i ich wpływ na kolejne etapy procesu wydobycia, właściwe rozplanowanie tych prac wymaga wielkiej uwagi i uwzględnienia kwestii technicznych, ekonomicznych a także bezpieczeństwa pracy. Dlatego też wybór najodpowiedniejszego schematu prowadzenia prac strzałowych zdefiniować można jako wieloatrybutowy problem decyzyjny (MADM – Multi Attribute Decision Making).

Metoda przyporządkowania liniowego jest jedną z metod mających zastosowanie w rozwiązywaniu problemów decyzyjnych. W obecnej pracy metoda ta wykorzystana została po raz pierwszy do oceny schematów prowadzenia prac strzałowych w kopalni, w procedurze uwzględniono parametry techniczne oraz parametry związane z bezpieczeństwem. Zaprezentowano wybrany przy pomocy metody najko-

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rzystniejszy schemat prowadzenia prac strzałowych w kopalni miedzi Sungun: nadkład 3.5m, odległości pomiędzy otworami 4.5 m, zastosowana przybitka 3.8 m, długość otworu strzałowego 12.1 m.

Słowa kluczowe: schemat prowadzenia prac strzałowych, modele decyzyjne MADM, metoda przyporządkowania liniowego, studium przypadku, kopalnia miedzi Sungun

1. Introduction

One of the most important operations in mining operation is Blasting (Hudaverdi, 2012; Kecojevic & Radomsky, 2005; Monjezi & Rezaei, 2011). Selecting suitable pattern causes to reduction of blasting costs and operational problems in following mining stages. Blasting patterns have been evaluated using experimental methods based on trial and error operations (Inanloo Arabi Shad and Ahangari, 2012). Considering abundance of alternatives and parameters on which evaluation of blasting patterns is based, selection of suitable pattern is complex decision for designers. Therefore, it seems necessary to use modern decision-making methods.

Suitable blasting pattern should be economically and technically acceptable (Hudaverdi, 2012; Sanchidrián et al., 2006). In the evaluation of the most suitable blasting patterns, Environmental effects of blasting should be also considered in order to provide desirable safety condition (Hudaverdi, 2012; Kecojevic & Radomsky, 2005). The main aim of blasting operation in mine is generation of Suitable fragmentation size and diminution of undesirable effects such as ground vibration, fly rock, back break etc. (Monjezi & Rezaei, 2011).

Mean size of fragmentation has been considered as main factor in evaluation of blasting patterns so far (Ghasemi et al., 2012a; Kulatilake et al., 2010; Michaux & Djordjevic, 2005; Morin & Ficarazzo, 2006; Sanchidrián et al., 2006). selecting of blasting patterns, only regarding fragmentation size factor, causes to neglect effect of other technical parameters such as back break, fly rock, ground vibration , air blasting etc., unless where these effects lead to some problems in mine.

Back break has been known as a destructive phenomenon in mines, thus designers attempt to forecast and prevent this problem in the new blasting bench (Gate et al., 2005; Khandelwal and Monjezi, 2012; Monjezi et al., 2012; Monjezi and Dehghani, 2008; Monjezi et al., 2010b). In order to achieve a reasonable fly rock distance for providing safety in mine, decrease of fly rock is one of the main worries of the blasting designers (Amini et al., 2011; Bajpayee et al., 2002, 2003, 2004a, 2004b; Ghasemi et al., 2012a, 2012b; Kecojevic & Radomsky, 2005; Little & Blair, 2010; Monjezi et al., 2012; Ning, 1999; Rehak et al., 2001; Rezaei et al., 2011; Stojadinović et al., 2011; Tota et al., 2001). In some cases that ground vibration and air blasting has caused some problems in mines designer should predict these phenomena and redesign blasting pattern (Ak et al., 2009; Bakhshandeh Amnieh et al., 2012; Dehghani & Ataee-Pour, 2011; Guosheng et al., 2011; Hudaverdi, 2012; Iphar et al., 2008; Monjezi et al., 2010a, 2011; Shuran & Shujin, 2011).

In hazardous and complicated fields of sciences such as mining engineering, advanced decision making methods such as MADM could have undeniable application. Because of sensitivity of decision making and necessity to consider different indexes for selecting appropriate alternative, multi attribute decision making methods have contributed to various subjects. implementation of this method in the mining engineering can be noted as: Ranking of risks in mines and tunnels, selecting mineral machinery and equipment, ranking hazards of underground mines, selecting suitable place for damping mineral and waste (Ataei et al., 2008; Bazzazi et al., 2008, 2011; Bejari et al., 2010; Guoliang & Sijing, 2010; Lashgari et al., 2010, 2011, 2012; Mikaeil et al., 2009; Monjezi et al., 2007; Peijie & Baozhu, 2011; WU et al., 2007; Yazdani-Chamzini & Yakhchali, 2012).

Considering the presented material, it is essential to have a model which can assess blasting patterns in terms of different points of view using experts' opinions. In this paper, linear assignment method (LA) which is a very technical and strong MADM model has been used for prioritizing the blasting patterns to evaluate and rank them in Sungun Copper Mine. Finally, most suitable one has been selected.

2. Case study

The Sungun copper mine is the largest open pit copper mine in Iran and located in the East Azarbaijan province, Iran, 125 km North West of Tabriz (Fig. 1). This mine is part of the global copper belt (Alp-Himalia) and situated in the middle of Qarabagh Mountains with about 2390 altitude from open sea. Estimated reserves is about 995 million tons of copper ore. Concentration process carries directly at the mine with a capacity of 170,000 tons of copper concentrates. Drilling and blasting are usual methods applied for the mine exploitation. The main explosive used for such operation is ANFO with dynamite as primer.

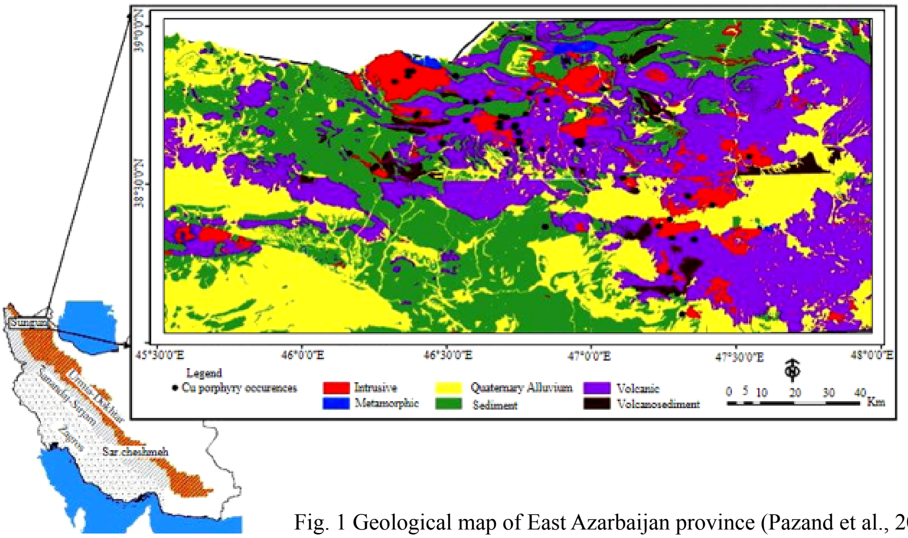

Fig. 1 Geological map of East Azarbaijan province (Pazand et al., 2012)

2.1. Geometrical properties of mine and blasting patterns

Sungun copper deposit is a Porphyry resource that involves numerous dikes with near- vertical slope and North-North West and North-West directions. The body of this porphyry deposit includes the mineralization of Monzonite to Quartz Monzonite. Along mining design process, final slope of 37 degrees for final walls, bench height of 12.5 meters, bench Width of 9.6 meters, bench incline of 65 degrees and road width of 24 meters is considered. To achieve the most proper blasting pattern in Sungun copper mine, different patterns are implemented that the geometric parameters of these patterns are as follows:

TABLE 1

Geometrical features of implemented blasting patterns

	Hole diameter inch	Hole Length m	Spacing m	Burden m	Stemming m
Pattern 1	5.5	12.1	4.5	3.5	3.8
Pattern 2	6	11.5	4.5	3.5	3
Pattern 3	5.5	12.5	4.5	3.5	3.6
Pattern 4	6	12.3	4.5	3.5	3.6
Pattern 5	5	13	5	4	3.8
Pattern 6	6	11.8	4.5	3.5	3.8
Pattern 7	5.5	12	4	3	3.2
Pattern 8	6	12.8	5	4	4.1
Pattern 9	5	13.5	5.5	5	4.5
Pattern 10	5.5	11.5	4	3	3.2
Pattern 11	5.5	11.5	4.5	3.5	3.6
Pattern 12	5	13.5	5	4	4.1
Pattern 13	6	13.2	5	4	3.5
Pattern 14	5	11	4.5	3.5	3.8
Pattern 15	5.5	13	4.5	3.5	4.1
Pattern 16	5.5	12	4.5	3.5	3.8
Pattern 17	5.5	13	5	4	3
Pattern 18	5	13.2	5.5	4.5	3.8
Pattern 19	6	12	5	4	4.1
Pattern 20	5.5	12.5	5	4	4.3
Pattern 21	5	13.2	5	4	4
Pattern 22	5	11	3.5	3	3
Pattern 23	5	12.8	4.5	3.5	4.1
Pattern 24	5	11.5	4	3	3
Pattern 25	6	12.9	5	4	4.1
Pattern 26	5.5	12.5	4.5	4	4
Pattern 27	5	11.8	4	3	3.2

3. MADM methods

Multi attribute decision making are methods in order to evaluation, prioritization and selection of the best available alternative (which sometimes should be done upon some opposite indices). In Multi attribute decision making problems; there are some alternatives which should be ranked. Any problem has several indices which are specify to each alternative and decision maker should define them accurately in the problems (Hwang & Yoon, 1981). Applied attributes in decision matrix are different from each other in terms of scale and unit.

Sometimes, indices have positive aspect and sometimes, they have negative aspect. Therefore, most proper alternative in a Multi attribute decision making models will be the alternative which provides the best state of each index (Hwang & Yoon, 1981).

3.1. Linear assignment method

Linear assignment method is one of the most important multi Attribute Decision Making methods (MADM). The linear assignment method (LA) sorts items based on the rating scores of each index. The final ranking of the items will be determined through a process of linear Reparation. Based on the property of simplex solution space, the linear assignment method, meanwhile considering all arrangements, extracts optimum answer in a simplex convex space. In addition, Reparative nature of index obtains by exchanging between the ranks and items albeit the index weight vector is obtained based on agent opinion. Combination of hard and soft techniques is the strength of LA method in compare with other MADM. The model is defined based on Complex mathematical equations in hard techniques and based on Contingency table in soft techniques. Combined Decision Techniques appears to follow the logic of the soft techniques with definition contingency table but in practice, the process of solving use Complex mathematical equations. Thus, Combined Decision Techniques have advantages of soft and hard techniques together. Using the LA technique may be summarized as follows (Hwang & Yoon, 1981):

Step 1: Determining the ranking of each item for each index as one $m \times m$ matrix that the row and Column indicate ranking and the index, respectively.

Step 2: Making the $m \times m$ assignment matrix or gamma (γ) matrix that the row and Column indicate item i and the ranking k, respectively. Component γ_{ik} is sum of index weights that item i have k rank. Gamma matrix is an assignment matrix and optimum answer can be obtained from any assignment techniques such as Transport, Hungarian method, grid method and linear programming method one and zero. The most common solution method in the linear assignment is Linear Programming method (Hwang & Yoon, 1981).

Step 3: Calculating optimum answer (final ranking) using linear programming method by following process:

$$\begin{gathered} Max\, Z = \sum_{i=1}^{m}\sum_{k=1}^{m}\gamma_{ik}h_{ik} \\ \sum_{k=1}^{m}h_{ik} = 1\,, \qquad i = 1,2,\ldots,n \\ \sum_{i=1}^{m}h_{ik} = 1\,, \qquad k = 1,2,\ldots,n \\ h_{ik} = 0\, or\, 1 \end{gathered} \tag{1}$$

The main features of this technique are:

a) Simple calculations and exchange between indexes due to using a simple ranking system of the items.

b) Matching of measurements units do not require and indexes can have different units.

4. Selecting most appropriate blasting pattern

Considering previous studies and investigations, in order to evaluation of the different blasting patterns in Sungun copper mine, five comprehensive and critical attributes are chosen by experts (Table). According to mentioned attributes and gathering real data from Sungun copper mine, 27 various blasting patterns implemented as input data for LA process. Hierarchical structure of problems is illustrated in Fig. 2.

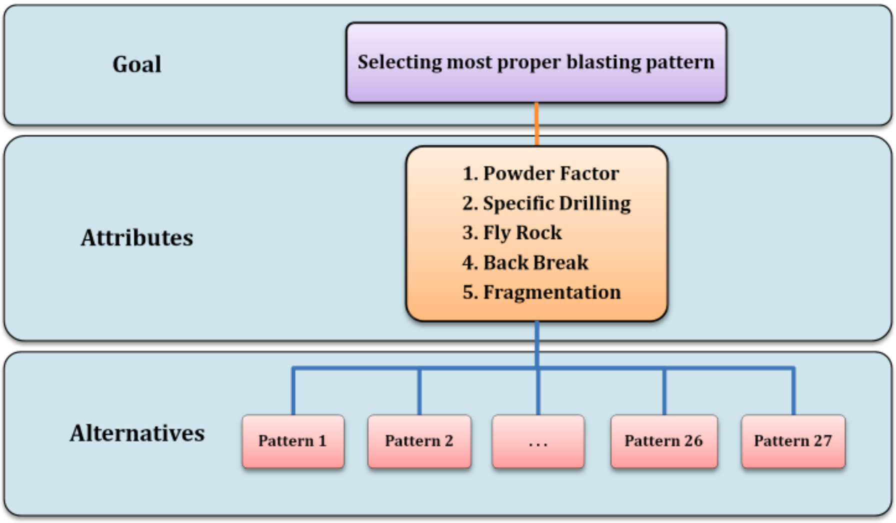

Fig. 2. Hierarchical structure of selecting most appropriate blasting pattern

TABLE 2

Evaluation Indexes for blasting patterns

Attribute	Symbol	Description
1	2	3
Powder factor	PF	Powder factor is the amount of explosives needed to break 1 cubic meter or 1 ton rock. This parameter is significant together with holes pattern and also the distribution of explosives in the rock mass has a large influence on the blasting results (Jimeno, 1995). The PF index has negative aspect because mining costs will raise with increasing PF and one blasting pattern with lower PF is most desirable (Jimeno, 1995).
Special drilling	SD	Special drilling is Length or volume of drilling per unit volume of rock. This parameter is function of blasting rocks Ability (Jimeno, 1995). The SD index has negative aspect because mining costs will raise with increasing SD and one blasting pattern with high SD is not suitable for mining.
Fly Rock	FR	Fly Rock a fast moving rock fragments from blasting point that is one of the reasons of damage to humans. Fly rock occur in front and top faces of blasted stops (Bajpayee et al., 2004a). Appropriate arrangements for blasting holes will make a lower rate of fly rock. The FR index has negative aspect and one blasting pattern with lower PF is most desirable.
Back break	BB	Broken rocks beyond the limits of the rear row of holes in a blast pattern can be defined as Back break. Distance between last row of holes and breakage bond is defined back break distance (Morin & Ficarazzo, 2006). Back break is an undesirable consequence of inappropriate blast design and thus has negative aspect.

Fig. 3. The weight of Attributes

1	2	3
Fragmen-tation	K	Average fragmentation is most important aspect that is controlled in blasting, because it has direct influence in cost of drilling and blasting and also economic aspects of later works such as loading, transportation and crushing (Cho & Kaneko, 2004). Earning favorite average fragmentation is necessary for every blasting pattern design. The K index has negative aspect because mining costs will increase with increasing rock fragments size and one blasting pattern with lower K is most desirable.

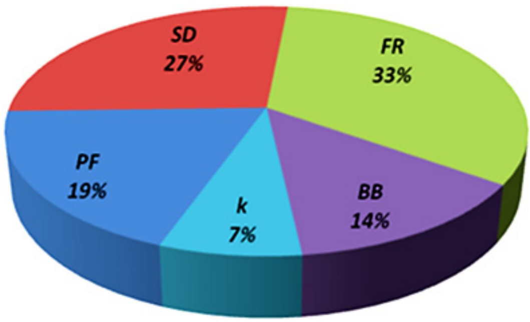

Fig. 3. The weight of Attributes

5. Making decision matrix and calculating weight of indexes

First step in application of multi-criteria decision-making methods is formation of decision matrix. Table includes different values of the indexes for 27 patterns as a decision matrix. Symbol P is an abbreviation of the word pattern. In the following, Combining 6 experts' opinions with average method, the weight of each index is obtained and the results are shown in Figure 3.

TABLE 3

Decision matrix

Pattern	PF (kg/m³)	SD (m/m³)	FR (m)	BB (m)	K (cm)	Pattern	PF (kg/m³)	SD (m/m³)	FR (m)	BB (m)	K (cm)
1	2	3	4	5	6	7	8	9	10	11	12
Pattern 1	0.36	0.05	72	2.5	31.0	Pattern 15	0.59	0.07	80	5.5	24.7
Pattern 2	0.34	0.05	75	2.0	31.5	Pattern 16	0.40	0.05	75	3.0	30.0
Pattern 3	0.42	0.05	76	3.0	30.0	Pattern 17	0.59	0.06	80	5.0	24.7
Pattern 4	0.43	0.05	76	3.0	31.0	Pattern 18	0.59	0.07	80	5.0	24.6
Pattern 5	0.40	0.05	75	3.0	32.0	Pattern 19	0.59	0.07	82	5.5	24.9
Pattern 6	0.41	0.05	76	3.0	29.0	Pattern 20	0.52	0.06	79	5.0	26.3
Pattern 7	0.38	0.05	75	2.0	30.1	Pattern 21	0.54	0.06	79	5.0	25.7
Pattern 8	0.59	0.07	80	5.0	24.7	Pattern 22	0.34	0.05	73	2.0	31.0

1	2	3	4	5	6	7	8	9	10	11	12
Pattern 9	0.85	0.09	85	9.0	20.8	Pattern 23	0.52	0.06	78	5.0	26.7
Pattern 10	0.37	0.05	74	2.0	30.2	Pattern 24	0.34	0.05	73	2.0	31.6
Pattern 11	0.40	0.05	76	3.0	31.0	Pattern 25	0.52	0.06	79	5.0	26.8
Pattern 12	0.59	0.06	78	5.5	24.7	Pattern 26	0.46	0.06	75	4.0	28.2
Pattern 13	0.59	0.07	81	5.5	24.6	Pattern 27	0.37	0.05	74	2.0	30.0
Pattern 14	0.40	0.05	76	3.0	30.0						

6. Prioritizing Blasting Patterns for Sungun Copper Mine using linear assignment method

Initially, the rank of all the items (blasting patterns) for each of the indexes is determined considering the decision matrix. According to the Table 4, one (5 × 27) matrix is formed that its rows are ranks and the columns are indicating the indexes. The next step in the LA method is making of assignment matrix. The row (i) and column (k) of this matrix are items (blasting patterns) and ranks, respectively. Assignment matrix Components are sum of index weights which item i have k rank (Table).

Finally, the ranking of items are obtained based on linear programming model (equation 1-3) by LINGO software. Given that the values of decision variables can be zero or one. Table shows the final results of the ranking of patterns based on LA method. As shown in Table , the pattern (P1) is allocated the first rank. Therefore, Pattern (P1) can be a suitable blasting pattern for Songun mine. Details of P1 pattern are 3.5 m burden, row spacing of 4.5 m, and length of holes 12.1 m and 3.8 m of Stemming length.

TABLE 4

Rank of all blasting patterns for each of the indexes

Rank	PF	SD	FR	BB	K	Rank	PF	SD	FR	BB	K
1	P2	P1	P1	P2	P9	15	P26	P12	P14	P26	P3
2	P22	P2	P22	P7	P13	16	P20	P17	P12	P8	P14
3	P24	P3	P24	P10	P18	17	P23	P20	P23	P17	P16
4	P1	P4	P10	P22	P8	18	P25	P21	P20	P18	P27
5	P10	P5	P27	P24	P12	19	P21	P23	P21	P20	P7
6	P27	P6	P2	P27	P15	20	P8	P25	P25	P21	P10
7	P7	P7	P5	P1	P17	21	P12	P26	P8	P23	P1
8	P5	P10	P7	P3	P19	22	P13	P8	P15	P25	P4
9	P11	P11	P16	P4	P21	23	P15	P13	P17	P12	P11
10	P14	P14	P26	P5	P20	24	P17	P15	P18	P13	P22
11	P16	P16	P3	P6	P23	25	P18	P18	P13	P15	P2
12	P6	P22	P4	P11	P25	26	P19	P19	P19	P19	P24
13	P3	P24	P6	P14	P26	27	P9	P9	P9	P9	P5
14	P4	P27	P11	P16	P6						

TABLE 5

Assignment matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
P1	0.36	0.00	0.00	0.19	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00
P2	0.31	0.31	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00
P3	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.05	0.00	0.19	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P4	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.05	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00
P5	0.00	0.00	0.00	0.00	0.31	0.00	0.05	0.19	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
P6	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.12	0.19	0.05	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P7	0.00	0.12	0.00	0.00	0.00	0.00	0.50	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P8	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.19	0.05	0.31	0.00	0.00	0.00	0.00	0.00
P9	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
P10	0.00	0.00	0.12	0.05	0.19	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.12	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00
P12	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.05	0.00	0.00	0.00	0.00	0.19	0.00	0.12	0.00	0.00	0.00	0.00
P13	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.31	0.12	0.05	0.00	0.00
P14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.12	0.00	0.05	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P15	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.19	0.31	0.12	0.00	0.00
P16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.50	0.00	0.00	0.12	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P17	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.12	0.00	0.00	0.00	0.00	0.00	0.05	0.19	0.00	0.00	0.00
P18	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.05	0.50	0.00	0.00
P19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00
P20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.19	0.31	0.05	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.24	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P22	0.00	0.24	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
P23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.31	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
P24	0.00	0.00	0.24	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
P25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.36	0.00	0.12	0.00	0.00	0.00	0.00	0.00
P26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.33	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00
P27	0.00	0.00	0.00	0.00	0.05	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 6

Final ranking of patterns based on LA method

Pattern	Rank	Pattern	Rank	Pattern	Rank
Pattern 1	1	Pattern 10	8	Pattern 19	26
Pattern 2	9	Pattern 11	23	Pattern 20	17
Pattern 3	3	Pattern 12	15	Pattern 21	18
Pattern 4	2	Pattern 13	2	Pattern 22	12
Pattern 5	5	Pattern 14	10	Pattern 23	19
Pattern 6	14	Pattern 15	24	Pattern 24	13
Pattern 7	7	Pattern 16	11	Pattern 25	20
Pattern 8	4	Pattern 17	16	Pattern 26	21
Pattern 9	27	Pattern 18	25	Pattern 27	6

7. Conclusion

Blasting is one of most sensitive operations in mining. This operation inherently is dangerous and any negligence about selecting suitable blasting pattern leads to irreparable damages to mine. Thus safety in mines is discernibly relevant to have proper blasting pattern. Appropriate blasting pattern should be acceptable in terms of all technical, environmental, safety and economical attributes. There for it is necessary to have a model to decide about most proper blasting pattern.

In this paper MADM methods are regarded as applicable models for evaluating blasting patterns because it will be very difficult to make decision about the most suitable blasting pattern due to variety of the operated blasting patterns and the number of impressive attributes which interfere in evaluation of blasting patterns. Finally, using linear assignment (LA) method, pattern 1 with burden of 3.5 m, spacing of 4.5 m, stemming of 3.8 m and hole length of 12.1 m is selected as the most suitable pattern in Sungun Copper Mine among the operated patterns.

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