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Prediction of Roof Failure in Pre-driven Entries and Selecting a Suitable Type of Recovery Room Method in Longwall Mining

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Abstract

In this work, two rock engineering system (RES)-based models are presented, the first model to predict the roof failure when a longwall face advances toward a pre-driven recovery room (PDRR) and the second model to select the type of recovery room method for longwall mining. For the first model, an international database of 43 case histories from the pre-driven rooms including technical parameters and type of corresponding operation outcome of each case history is considered. In this regard, a vulnerability index (VI) that refers to the risk of roof failure is calculated for each case history and the VIs are compared with the type of the corresponding outcomes. The obtained results indicate that the calculated VIs have a good adaptation with the corresponding outcomes. This approach could be used to analyze the risk of failure in PDRR, and determine the critical VI that specifies the boundary between the hazard range and the safe range that leads to an accurate operational planning. In the following, a method called multi-options RES-based model (MORESM) is adopted for the selection of recovery room methods in longwall operation. By this model, selecting the optimum option from several options in terms of many effective parameters on the system is possible. Based on the evaluations, CRR, PDRR3, and PDRR2&3 are the suitable options for the case study. This model could introduce the suitable option based on geotechnical conditions but the final decision depends on the economic policy of the managing team.

1. Introduction

Taking proper decisions on applying the type of recovery room method is one of the important concerns in longwall mining operations. Implementing proper methods results in safe operation, time-saving, reducing operation costs, and increasing productivity. The conventional recovery room (CRR) and the PDRR are two methods to be implemented to withdraw longwall face equipment (Figure 1). The PDRR method is divided into several sub-methods, each with its advantages and disadvantages. When a longwall face advances toward pre-driven entries, investigation of the likely roof failures is another concern which, according to geotechnical and geomechnical conditions, can occur. Based on related studies, failure of roof strata in pre-driven entries can be divided into two categories including roof fall failure and weighting failure [1-5]. Accordingly, determining the type and probability of occurrence of these failures are very important for the implementation of pre-driven entries.

Stability analysis, associated hazards, and preferences of selection for the type of recovery rooms have been studied by several researchers in the past. Bauer et al. (1989) assessed the feasibility of using the PDRRs to increase the productivity of coal extraction [6]. Oyler et al. (2001) collected an international comprehensive database consisting of 131 case histories from different mines around the world to determine the effective factors on failures in pre-driven

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roadways. They also investigated conditions of all roof support elements including shields, rock bolts, and stand supports when the roof failures occur [1]. Peng (2006) explained if the roof condition in the designated recovery room location is bad, an open recovery room provides an excellent opportunity to pre-support the roof, and ensures its stability during the recovery operation. Peng stated that PDRR with complete backfill can be used when the roof is very weak and cannot maintain any entry roof span when the front abutment pressure arrives [7]. Applying a backfill method can have advantages and disadvantages. Kulekci and Aliyazicioglu (2018) compared backfill methods in underground mining. Using the extracted waste in mines is one of the benefits of the backfill method. In this regard, the capability of applying the waste should be analyzed by laboratory tests [8]. Kulekci et al. (2021) studied the usability of waste by experimental tests [9]. According to the literature review, weighting failure and roof fall are two serious hazards when the entrance of a longwall face to PDDR that their risk must be assessed before the application. Tadolini and Barczak (2008) analyzed the rock mass behavior and support response in a PDRR supported with pumpable concrete roof cribs and provided results about the induced stresses, displacements, and instabilities in elements of the PDRR including inby and outby pillars, and roof [10]. Wichlacz et al. (2009) presented a program to evaluate the use of pre-driven recovery method based on the six investigated and specified factors including floor strength, CMRR (coal mine roof rating), extraction depth, reinforcement density index (RDI), the capacity of standing support, and mining rate. In this regard, some case studies have been analyzed to discover which parameters have the greatest influence on the success of pre-driven recovery [3]. Gearhart et al. (2014) studied the behavior of a PDRR under a depth of less than 200 ft. They expressed that low depth of cover along with the difficult geology of the roof creates challenging conditions. This refers to low interlocking forces in the strata than the deeper mines. They also explained the joints and shallow depth result in heavy loading on the installed support and shields [11]. Campbell (2015) investigated a big roof fall in a longwall face when the shields were removed from the work face. Two main factors had a basic role to play this accident including the existence of a faulted roof with high inclined joints and a failed coal face [12]. Kang et al. (2015) set a study to examine the ground response of a PDDR [13]. Rutty et al. (2016) emphasized in this keynote that PDRR method can improve the longwall take-off in weak roofs. The paper describes the evolution of applying the PDRR method in a case study. The final version was modified PDRR with a backfill strategy [14]. Zhu et al. (2017) indicated how problematic roof falls could occur near the longwall recovery area when the adapting roadways were used in deep depths. They believe that the adapting roadways induce more deformation in coal and roof that extend the instabilities in the immediate roof leading to big roof falls and then weighting failure [4]. Liu et al. (2018) analyzed the accidents and failures when a longwall face was advancing toward an abandoned roadway. They stated that the failure of the main roof ahead of the workface caused transferring the instability to higher strata and weighting failures that induce a significant load on supports that leads to an accident. The research work proposes a partial backfill technique for abandoned roadways to prevent the accident [5]. Zorkov et al. (2020) investigated the parameters design for PDRR by analyzing the roof support load. They expressed that the maximum number of failures in the entrances to PDRR have occurred in two areas including depths of up to 300 m and areas with hard-to-control roofs and depths over 600 m and two types of hard-to-control and medium-controlled roofs [15]. Zhu et al. (2020) studied the stability of strata around longwall recovery roadways in shallow depths. They proposed an approach to analyze the loads on support systems in shallow depths to determine the sufficient support capacity and reasonable width of the recovery room. The failure analysis in various research works states this point that applying the PDRR methods are preferred to the conventional method when the instabilities are limited to the immediate roof. However, when the main roof is exposed to instability, weighting failures can generate many problems for the implementation of PDRR method [16].

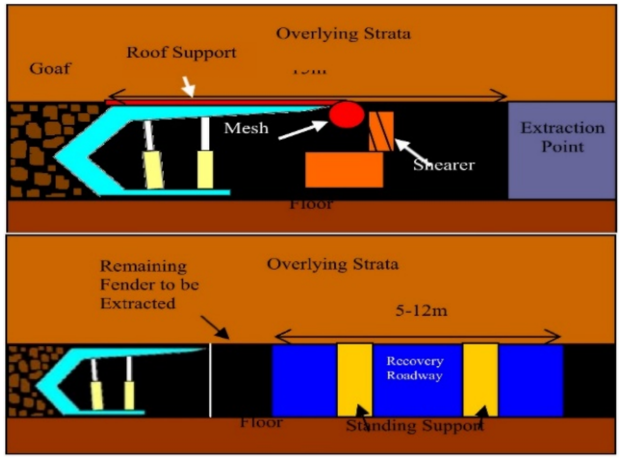

Figure 1. Schematic representations of CRR and PDRR methods (Wichlacz *et al*. 2009).

In this research work, two RES-based models are presented for prediction of roof failure in pre-driven entries and selection of the type of recovery room method in longwall mining, respectively. RES introduced by Hudson (1992) is based on an interaction matrix to investigate the interactions between the parameters in the rock mass and determine their weight in the system [17] (Figure 2). The first model is focused on the risk analysis of roof failure (roof fall type or weighting roof failure) in pre-driven open entries when a longwall face advances toward the roadway. In this regard, a database including 43 case histories taken from a carried-out study by Oyler *et al*. (2001) is considered [1]. The second model provides an approach to calculate the risk of implementing recovery room methods in longwall mining. This process results in the selection of optimum methods with minimum risk of failure in considered conditions. The second model is applied for the selection of the recovery room method in Parvadeh-I coal mine, Iran. CRR method is used to withdraw longwall face equipment in this mine.

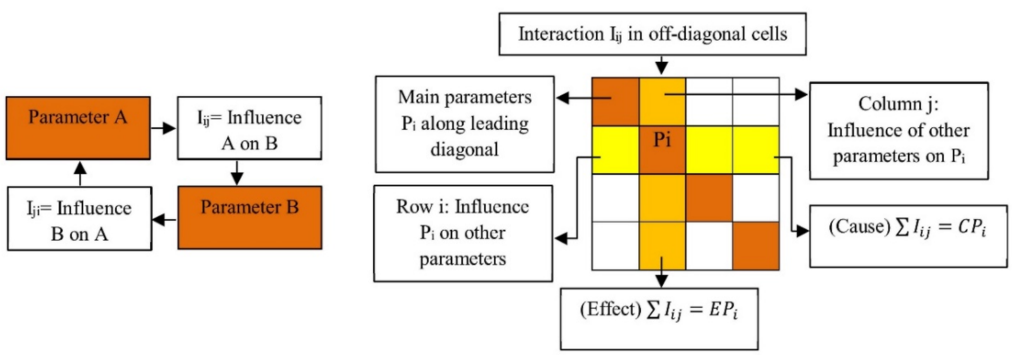

Figure 2. A general view of interaction matrix including principles of the interaction between parameters and the matrix coding (taken after Hudson (1992) [17]).

2. Prediction of Roof Failure in Pre-driven Entries

Recovery of longwall face equipment by pre-driven entries has significant advantages but there are some spectacular failures. Oyler *et al.* (2001) have compiled a comprehensive international database of 131 case histories to determine what factors contribute to such failures. Based on these investigations, two major types of room failures mechanism were suggested consisting of roof fall type failure and overburden weighting type failure [1]. In this database, the outcome parameter reports the stability status during the operation in pre-driven entries that has been divided into three categories including successful outcome, failure due to face break of face fall, and failure due to major overburden weighting. Investigations and available data shared by Oyler *et al.* (2001) are the basis of our research in this section for presenting a model for the prediction of roof failure in pre-driven entries [1]. Table 1 illustrates some considered cases.

Table 1. Information of 7 cases from considered database.

Country	Ni. Of Rooms	Soft Floor	Depth m	CMRR	Seam height (m)	Panel Width (m)	Room Length (m)	Room Width (m)	Shield Capacity tones	RDI (MPa)	Standing support tones MPa	Slow mining	Outcome
USA	1	N	150	40	2.4	244	61	6.1	454	0.37	5.6	N	1
USA	1	N	150	40	2.4	183	183	5.2	454	0.43	5.6	N	1
USA	1	N	220	40	2.2	305	305	6.7	635	0.88	0	N	3
Australia	1	Y	90	60	3.1	200	200	4.2	590	0.64	0.1	N	1
Australia	1	N	190	50	2.4	200	200	5.2	726	0.76	0.14	N	3
South Africa	1	Y	70	35	3	200	100	5	327	0.55	0	Y	3
USA	1	N	610	57.5	2.5	76	76	6.1	590	0.15	0	N	2

Description of abbreviations in the table:
Soft Floor. Y = Soft. N = Normal or not noted as soft by the original source.
CMRR = Coal Mine Roof Rating.
RDI = Reinforcement Density Index.
Slow Mining. Y = Slow Mining. N = Normal Mining or rapid mining or rate unknown.
Outcome. 1 = Successful outcome. 2 = Failure due to face break or face fall. 3 = Failure due to major overburden weighting.

Eleven factors were considered by Oyler *et al.* (2001) including coal mine roof rating (CMRR), floor quality, depth of the room, seam height, mining rate, panel width, room width, room length, shield capacity, roof reinforcement density index (RDI), and standing support density [1]. RDI is the product of the support capacity and the support length, divided by the tributary area affected by the support and summed for all support types. According to the results of this paper and the investigations of the present study, seven major effective parameters on roof failure in pre-driven entries were selected for the RES-based model in this section. These parameters were P1: CMRR, P2: the ratio of panel width to panel depth, P3: compatibility index of shield capacity (SCCI), P4: roof reinforcement density index (RDI), P5: compatibility index of standing support density (SSDCI), P6: floor quality, and P7: height of coal seam.

The influence of panel width and depth of mine was considered by the ratio of panel width to panel depth. This parameter well-expresses the effect of depth and panel width. Although the relationship between these two parameters with roof failures investigated by Oyler et al. (2001), considering the ratio of panel width to panel depth (P_2) provides a more transparent concept that the obtained results are illustrated in Figure 3. Also two factors named the compatibility index of shield capacity (Equation (1)) and the compatibility index of standing support density (Equation (2)) were developed for better expressing the influence of support capacity and standing support index, respectively. In these equations, seam height (Hs) is used as a normalization factor. The results of these investigations are shown in Figures 4 and 5.

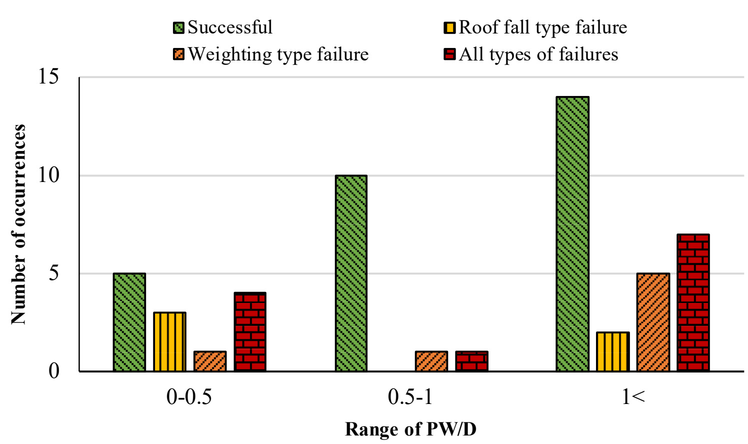

Figure 3. Relationship between the P2 and number of recorded occurrences in pre-driven entries.

$$SC_{CI} = \frac{SC}{H_s} \quad (1)$$

$$SSD_{CI} = \frac{SSI}{H_s} \quad (2)$$

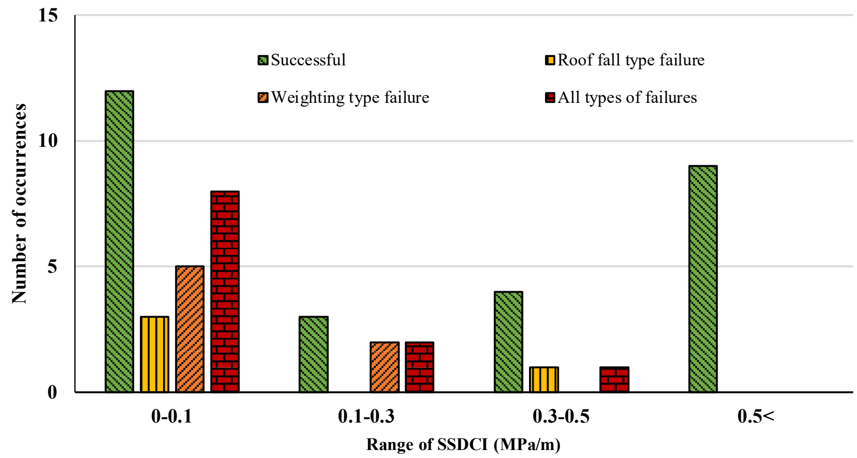

Figure 4. Relationship between the SSDCI and number of recorded occurrences in pre-driven entries.

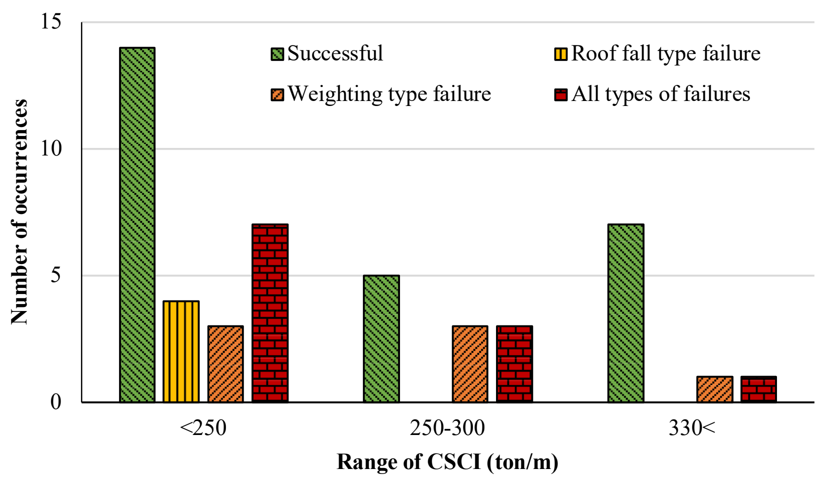

Figure 5. Relationship between the CSCI and number of recorded occurrences in pre-driven entries.

The interaction matrix was performed containing the seven considered effective parameters (Table 2). The off-diagonal positions in the matrix are filled by values describing the degree of interaction between the parameters. This research work has adopted the ‘‘expert semi-quantitative’’ (ESQ) method (Hudson 1992) to numerically coding the interaction matrix in such a way that 0 for “no interaction”, 1 for “weak”, 2 for “medium”, 3 for “strong”, and 4 for “critical” interaction, respectively. In the matrix, each particular parameter is denoted as coordinates (C (cause), E (effect)). C_i is the cause of P_i equal to the sum of values in the i_{th} row, and E_i is the effect of P_i equal to the sum of the values in the i_{th} column, in the matrix. Subsequently, the weighting factor of each parameter was determined by Equation (3), and the results are illustrated in Figure 6. The weighting factor values represent the interactive intensity value of each parameter. As it could be seen in Figure 6, SSD_{CI}, SC_{CI}, RDI, and CMRR appear to have the highest weights in the system, and could highly influence the other elements, respectively.

$$a_i = \frac{(C_i + E_i)}{(\sum_{i=1}^{n} C + \sum_{i=1}^{n} E)} \times 100 \quad (3)$$

where C_i is the cause of the i_{th} parameter and E_i is the effect of the i_{th} parameter (for more information, see Hudson 1992) [15].

Table 2. Coding of interaction matrix for first model.

P_1	1	3	4	4	0	1
0	P_2	2	1	2	2	1
0	1	P_3	2	2	0	0
0	0	0	P_4	2	0	0
0	0	0	2	P_5	0	0
0	0	2	1	1	P_6	1
0	1	3	1	2	0	P_7

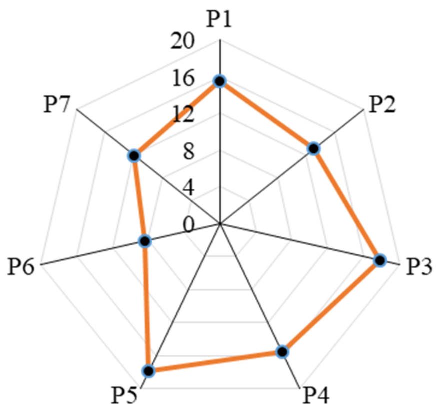

Figure 6. Weighing factor of the principal parameters in first model.

To analyze the risk of roof failure and its prediction, Equation (4) was applied. The vulnerability index concept has been developed by Benardos and Kaliampakos (2004). The vulnerability index (VI) was used as an overall indicator of the potential problems encountered (roof failure types including roof fall and weighting failure) in pre-driven entries. In Equation (4), VI is the vulnerability index, a_i is the weighting of the i_{th} parameter, Q_i is the value (rating) of the i_{th} parameter, and Q_{max} is the maximum value assigned for the i_{th} parameter (normalization factor) [18].

$$VI = 100 - \sum_{i=1} a_i \frac{Q_i}{Q_{max}} \tag{4}$$

To compute the Q_i/Q_{max} in Equation (4), the rating of parameters value was specified based on their effect on the occurrence of roof failure when a longwall face advances toward a pre-driven entry. In the maximum number, five classes of rating, ranging from 0 to 4, were considered, where 0 identifies the worst case (maximum risk of roof failure) and 4 identifies the best case (minimum risk of roof failure). Rating the parameters are presented in Table 3 on the basis of experts' views, results of Figs. 2 to 4, and results of the carried-out research work by Oyler *et al*. (2001) [1].

Table 3. Rating of the principal parameters effect in first model.

Parameter code	Value/description and rating					
P_1	Value	0-25	25-45	45-65	65-100	
	Rating	0	1	2	3	
P_2	Value	0-0.5	0.5-1	1 <		
	Rating	0	2	1		
P_3	Value	< 250	250-300	300 <		
	Rating	0	1	2		
P_4	Value	< 0.5	0.5-1	1-1.5	1.5 <	
	Rating	0	1	2	3	
P_5	Value	< 0.1	0.1-03	0.3-0.5	0.5 <	
	Rating	0	1	2	3	
P_6	Value	Y	N			
	Rating	0	1			
P_7	Value	< 1	1-1.5	1.5-2	2-3	3 <
	Rating	4	3	2	1	0

Y = Soft floor. N = Normal or not noted as soft by the original source.

Here, a database consisting of 43 case histories was taken from the carried-out study by Oyler *et al*. (2001); incomplete data was removed (see Table 1 in the article released by Oyler *et al.* (2001)) [1]. By using Equation (4), the VI of roof failure was calculated for each case, and a description of the obtained results is presented in Table 4. The relationship between the calculated VI and the outcome of each case is illustrated in Figure 7. Determining the boundary between VIs of successful outcomes and VIs of failure outcomes results to evaluate the critical VI (see Table 4 and Figure 7). Critical VI specifies the boundary between the hazard range and the safe range. In a considered condition, when a longwall face advances toward a pre-driven room, if the calculated VI is more than the critical VI, the roof failure is probable.

Table 4. Statistical results of the calculated VIs of outcomes for considered database in first model.

Item	Ave. VI	Min VI	Max VI	St. Dev.
Cases with successful outcome	55.63	30.36	81.35	16.12
Cases with roof fall type failure	74.50	65.08	78.37	6.37
Cases with weighting roof type failure	69.54	48.81	85.32	13.65
Cases with both types of failure	71.53	48.81	85.32	11.11

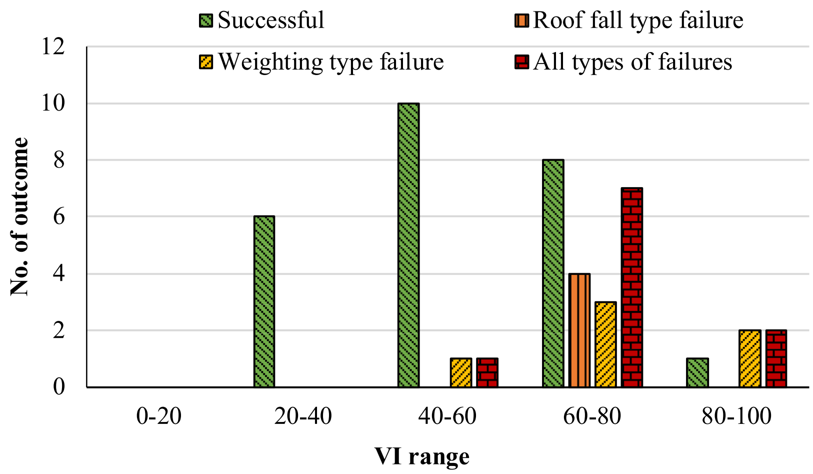

Figure 7. Distribution of calculated VIs of roof failure against the number of recorded occurrences.

3. Generation of MORESM for Selection of Recovery Room method

In this section, an approach entitled multiple-option RES-based model (MORESM) is adopted to the selection of the recovery room method. MORESM uses a rating matrix instead of the conventional rating method that was applied in the first model in the previous section. This method presents a new application of RES, which provides a tool to select the optimum option from several options in terms of the influence of many effective parameters on the system. Based on the literature review, six recovery room methods (Figure 8) were considered in this study including the conventional recovery room method (CRR), the pre-driven recovery room with roof and/or rib bolt reinforcement only–no standing support (PDRR1), the pre-driven recovery room with standing supports without roof and/or rib bolt reinforcement (PDRR2), the pre-driven recovery room with backfilled method reinforced by the roof and/or rib bolts (PDRR3), the pre-driven recovery room with standing supports and roof and/or rib bolt reinforcement (PDRR1&2) and the pre-driven recovery room with the backfilled method and roof and/or rib bolt reinforcement and standing supports (PDRR2&3).

Based on investigations and obtained results of previous sections, seven major effective parameters on selecting the method of recovery room in longwall mining were identified and considered to the MORESM. These parameters were P_1: CMRR, P_2: position of cantilever strong bed in roof, P_3: floor RMR (rock mass quality), P_4: the ratio of panel width to depth, P_5: safety factor of longwall face, P_6: longwall inclination, and P_7: joint condition factor (JC). The JC is defined according to presented information in Table 5 ranging from 0 to 20 referring to the worst and best joint condition. The JC is one of the factors calculating the probability of forming a roof fall in front of powered supports in the recovery room in the presented model. Furthermore, the reaction matrix was formed and related results are illustrated in Table 6 and Figure 9.

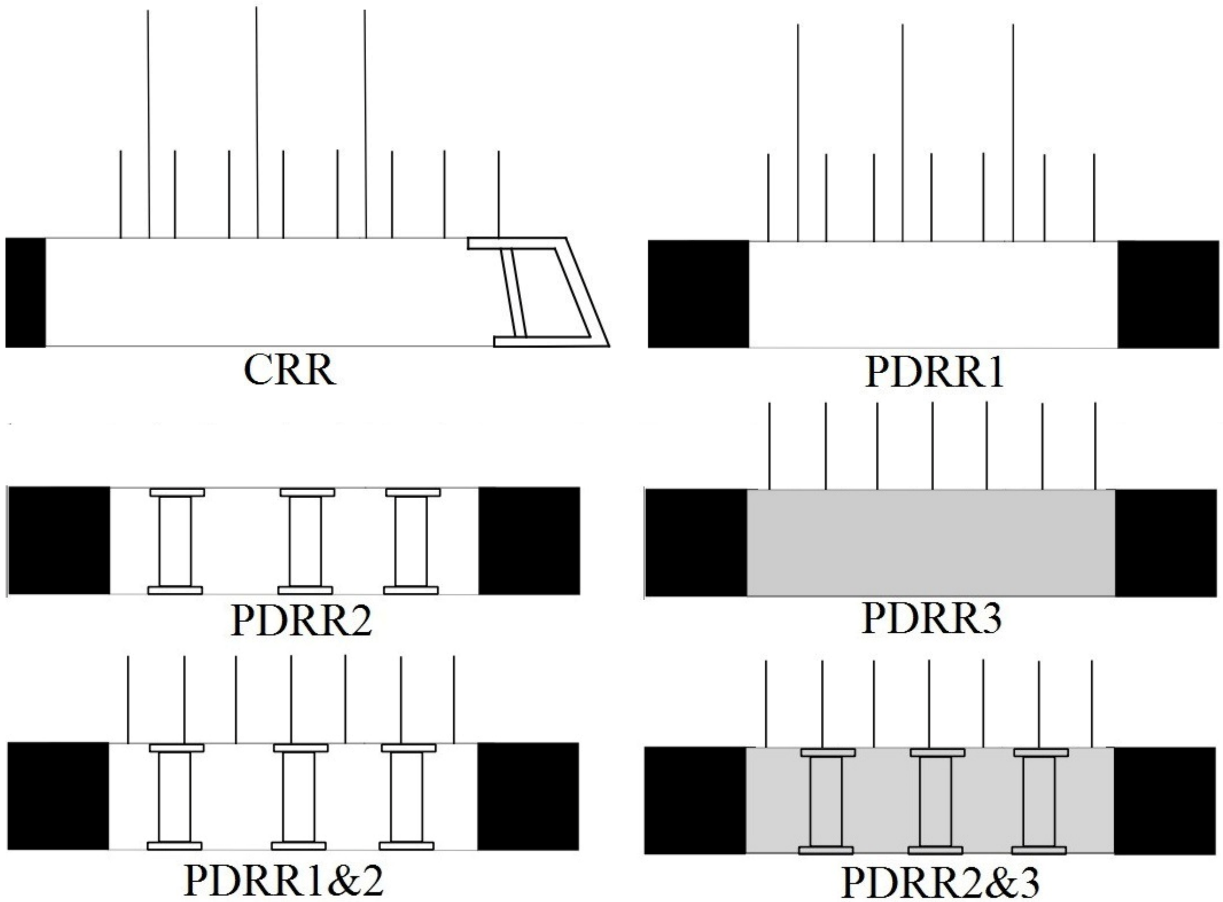

Figure 8. Six considered recovery room methods for second model.

Table 5. Rating table of Joint conditions factor (JC).

Item		Range/Rating				
Joint spacing	Range	S < 0.5	0.5 < S < 1	1 < S < 3	3 < S < 6	S > 6
	Rating	1	3	7	9	10
Joint dip	Range	75 < α < 90	60 < α < 75	0 < α < 60		
	Rating	0	3	6		
Joint strike (angle between longwall face and joint strike)	Range	B < 45	45 < β < 70	70 < β < 90		
	Rating	0	2	4		

Table 6. Coding of interaction matrix for the parameters affecting the selection of recovery room method.

P_1	0	0	1	1	0	0
3	P_2	0	1	2	1	1
0	0	P_3	2	1	1	0
0	0	0	P_4	1	0	0
0	0	0	0	P_5	0	0
0	0	0	2	1	P_7	0
2	0	1	1	1	0	P_9

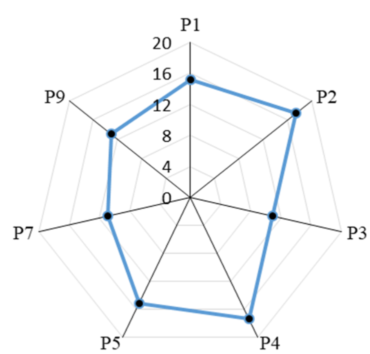

Figure 9. Weighing factor of the principal parameters in second model.

3.1. Rating method and calculation of VI

In the second model, there are six recovery room methods as six options that VI of applying each method be calculated by using Equation (4). Therefore, the method with lower VI is the optimal option in considered conditions. For this purpose, to calculate the Q_i/Q_{max} in Equation (4), the conventional ratings presented in articles of the recent years were not applicable. Therefore, a new rating method was needed. In this regard, a rating method was developed based on a rating matrix for simultaneous calculation of VI for several options (Figure 10). In the rating matrix of P_i, rating in two directions is carried out and checked. In the horizontal direction of the matrix, rating with aim of identifying the priority of considered option in different value ranges for P_i, and in the vertical direction of the matrix, rating with aim of identifying the priority of considered value range in different options for P_i was performed. To compute Q_i/Q_{max}, the biggest value in each rating matrix is considered as Q_{max} for the corresponding P_i. This rating method provides a tool for selecting the optimum option from several options.

Here, seven rating matrices were formed based on the selected parameters and six considered recovery room methods. For the second model, ratings and divisions were carried out based on the views of experts, Figure 3, results of the carried-out research by Oyler *et al*. (2001), and the literature review, and the results are illustrated in Figures 11 and 12 [1].

For P_2, $h_{im.max}$ is the maximum caving height of the immediate roof and it is determined by Equation (5) [1]. In Equation (5), H is the mining height at the longwall face and K is the volumetric expansion coefficient of caved rock.

$$h_{im.max} = \frac{H}{K-1} \tag{5}$$

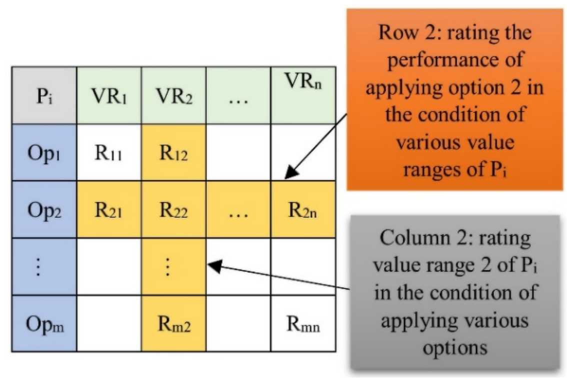

Figure 10. Rating matrix for MORESM.

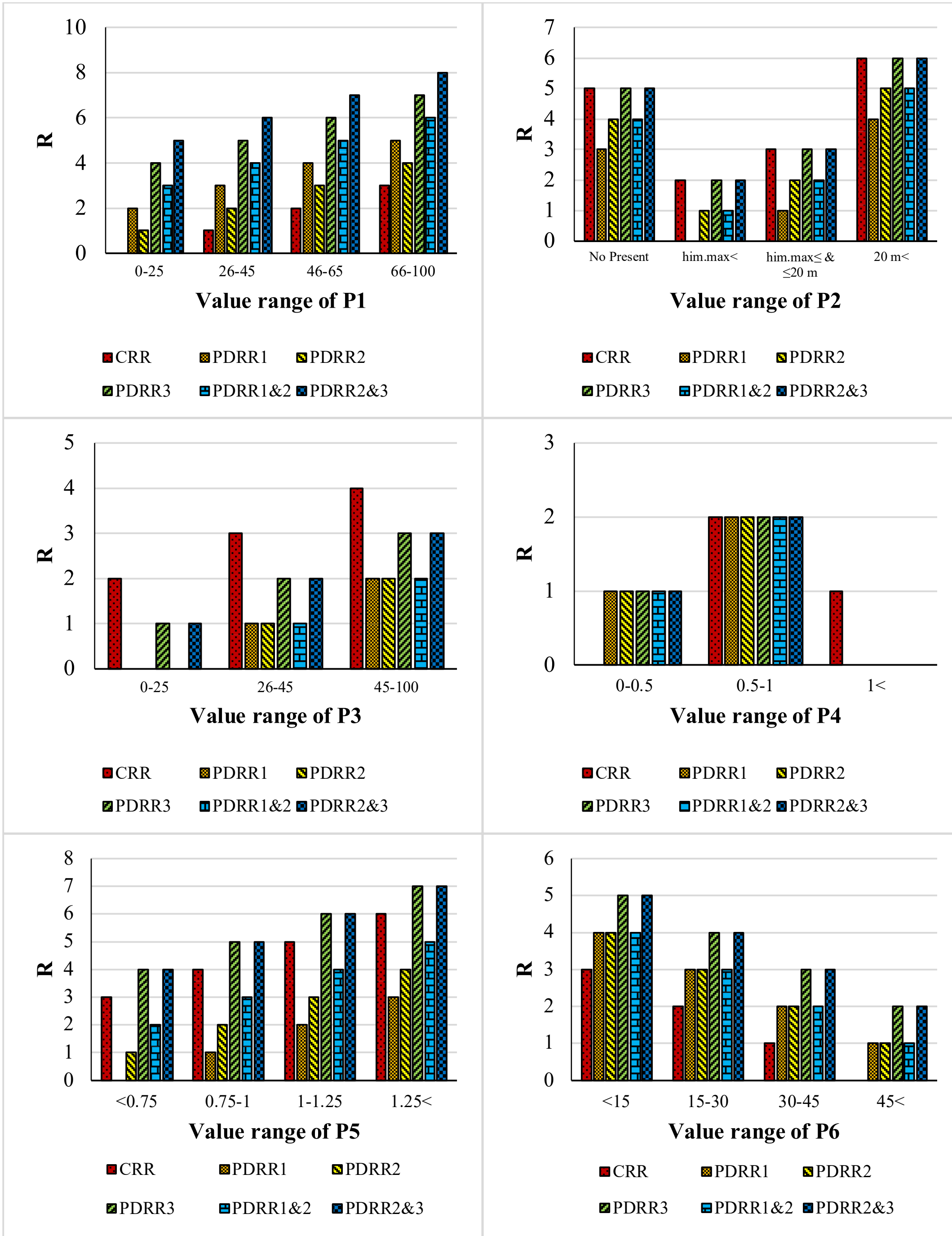

Figure 11. Rating of the P_1 to P_6, the results from the rating matrix of the P_1 to P_6.

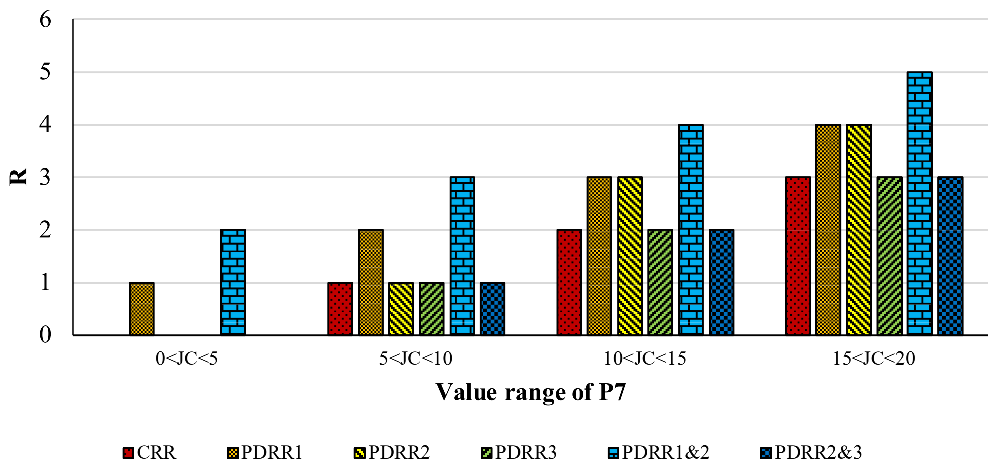

Figure 12. Rating of the P_7, the results from the rating matrix of the P_7.

3.2. Case study

The Tabas Parvadeh coal mine No. 1 is located in Tabas County, South Khorasan province. Five main coal seams have been explored (B1, B2, C1, C2, and D) at the coal deposit and currently C_1 is being worked [19-20].

To date, 8 excavation panels have been worked out. The MORESM was applied for selecting the recovery room method in Parvadeh-I coal mine, Iran. The CRR method is used to withdraw longwall face equipment in Parvadeh-I coal mine (Figure 13). In this regard, six longwall panels were considered in Parvadeh-I (Figure 14). Information of these panels is presented in Table 7. Based on the average of parameters value in each panel, the VI of each recovery room method was calculated and results are revealed in Figure 15.

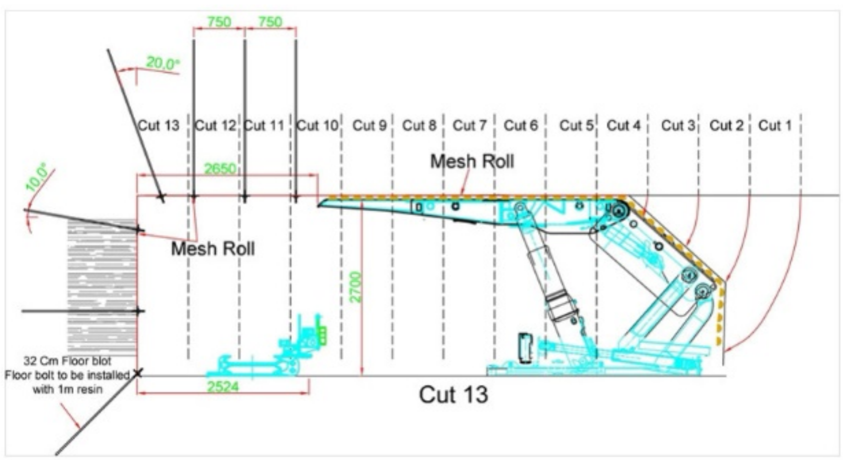

Figure 13. Sequences of the CRR operation in Parvadeh-I coal mine.

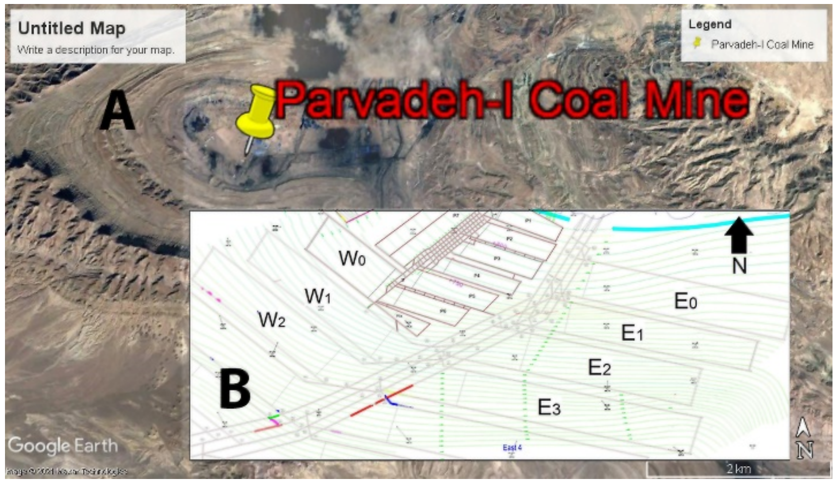

Figure 14. A is the location of Parvadeh-I in Parvadeh colliery, B is the layout of first longwall panels in Parvadeh-I coal mine.

Table 7. Information of the six considered longwall panels.

Panel	P_1 CMRR	P_2	P_3 Floor RMR	P_4 PW/D	P5 SF	P_6 Dip	P_7 JC
E_2	34	No Present	31	0.9	0.7	24.9	8
W_1	46	No Present	36	0.7	1.0	15.8	12
W_0	49	No Present	33	1.2	1.1	<15	12
E_0	46	No Present	39	2.1	3.1	12.4	8
E_3	33	No Present	35	0.6	1.8	19.0	8
W_2	50	No present	42	0.6	0.9	12.8	12

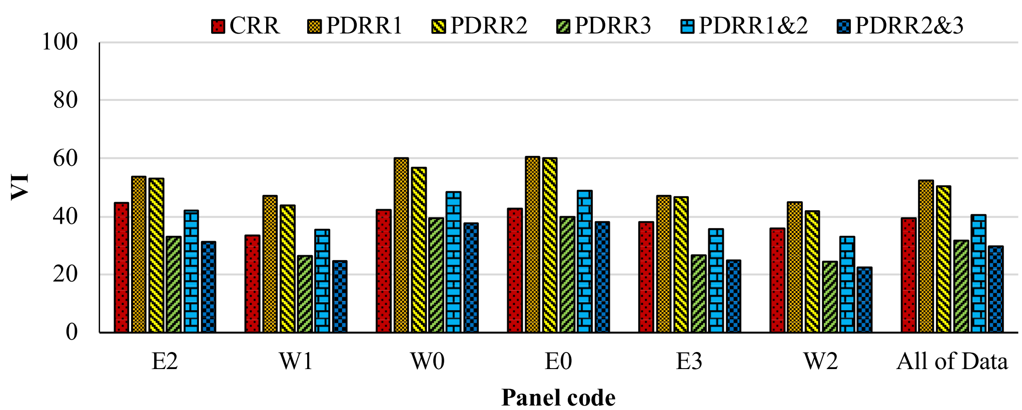

Figure 15. Comparing the calculated VI of each recovery room method in the considered panels.

4. Conclusions

In this paper, two RES-based models wereе presented, the first model to predict roof failure in pre-driven entries and the second model, named MORESM, to select the suitable recovery room method in pre-driven entries. In this regard, the following conclusions are stated:

The obtained results from the first model have a good adaptation with the recorded occurrence of roof failures. This good adaptation suggests that the proposed model can be useful to predict roof failure when a longwall face advances toward a PDRR. Moreover, the operational parameters can be optimized by determining the critical VI from the obtained results of the first model, critical VI specifies the boundary between the hazard range and the safe rangein such a way that in a given condition of non-operational parameters (CMRR, (PW/D) as a semi-operational parameter, floor quality, and seam height), the values of the operational parameters (SSD_{CI}, RDI, and SC_{CI}) should result in a VI lower than the critical VI. It is possible by the presented model providing tools for optimizing the support elements.

The results on selecting the optimum recovery room method (MORESM) in Parvadeh-I coal mine showed that PDRR2&3 and PDRR1&2 are the best options to implement the recovery room operation and withdraw longwall face equipment. In this mine, on the one hand, the coal face is usually broken and increases the unconfined span at the face. On the other hand, there is no cantilever strong bed in the roof and the immediate roof is weak. In addition, the floor failure had happened in some cases, which had disrupted the advancing operation of the powered supports and exacerbated the problems due to roof falls. These items have created complicated conditions. In such cases, MORESM could be applied to select the best method of recovery room. Of course, this model needs more investigation in various conditions.

In general, the presented approaches in this study could provide a capable tool for considering all conditions on the selection of optimum recovery room method for withdrawing equipment in a longwall panel face.

References

[1]. Oyler, D.C., Mark, C., Dolinar, D.R, and Frith, R.C (2001). A study of the ground control effects of mining longwall faces into open entries. Journal of Geotechnical and Geological Engineering.

[2]. Tadolini, S.C. and Barczak, T.M (2004). Design parameters of roof support systems for pre-driven longwall recovery rooms. SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-54. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., PP 1-13.

[3]. Wichlacz, D., Britten, T, and Beamish, B (2009). Development of a Pre-Driven Recover y E valuation Program for Longwall Operations. Coal Operators Conference. University of Wollongong & the Australasian Institute of Mining and Metallurgy, 23-36.

[4]. Zhu, W., Xu, J, and Xu, G (2017). Mechanism and control of roof fall and support failure incidents occurring near longwall recovery roadways. The Journal of the Southern African Institute of Mining and Metallurgy.

[5]. Chang, Liu., Zengqiang, Yang., Peilin, Gong., Kai, Wang., Xiaoqiang, Zhang., Junwen, Zhang, and Yulin, Li (2018) Accident Analysis in Relation to Main Roof Structure When Longwall Face Advances toward a Roadway: A Case Study. Advances in Civil Engineering.

[6]. Eric, R. Bauer, Jeffrey M. listak, and Mike, Berdine (1989). Assessment of Experimental Longwall Recovery Rooms for Increasing Productivity and Expediting Equipment Removal Operations. US. Bureau of Mines, Report of Investigations 9248.

[7]. Peng S.S. Longwall mining, 2nd Ed. Morgantown, West Virginia University. 2006.

[8]. Kulekci, G. and Aliyazicioglu, S. (2018). COMPARISON OF BACKFILL METHODS IN UNDERGROUND MINING. International Journal on Mathematic, Engineering and Natural Sciences. ISSN 2602 – 4136. Vol:5.

[9]. Kulekci, G.Yilmaz. A.O. and Cullu, M. (2021). Experimental Investigation of Usability of Construction Waste as Aggregate. Journal of Mining and Environment (JME), Vol. 12, No. 1, 2021, 63-76.

[10]. Tadolini, SC. and Barczak TM. (2008). Rock Mass Behavior and Support Response in a Longwall Panel Pre-Driven Recovery Room. The National Institute for Occupational Safety and Health (NIOSH). NIOSHTIC2 Number: 20033693. Proceedings of the 6th International Symposium on Ground Support in Mining and Civil Engineering Construction, Cape Town, Republic of South Africa, 167-182.

[11]. F. Gearhart D, H. Jones T, S. Compton, C, A. Minoski, T, E. and Ochsner, R. (2014). Ground Response as a Longwall Advances into a Backfilled Recovery Room under Low Cover. 33rd International Conference on Ground Control in Mining. West Virginia / United States

[12]. Campbell, R. (2015). Longwall Salvage Roof Fall Recovery Experience. 15th Coal Operators' Conference, University of Wollongong, The Australasian Institute of Mining and Metallurgy and Mine Managers Association of Australia, 62-72.

[13]. Hongpu, Kang. Huawen, Lv. Xiao, Zhang. Fuqiang, Gao. Zhigang, Wu. and Zhichao, Wang. (2015). Evaluation of the Ground Response of a Pre-driven Longwall Recovery Room Supported by Concrete Cribs. Rock Mech Rock Eng.

[14]. Yass-Marie, Rutty. Dan, Payne. and Adam, McKenzie. (2016). The Evolution of P re-driven Recover y Roadways at Crinum Mine. Coal Operators' Conference, University of Wollongong, Australia.

[15]. Zorkov, D. Renev, A. Filimonov, K. and Zainulin, R. (2020). The Roof Support Load Analysis for Pre-Driven Recovery Room Parameters Design. Vth International Innovative Mining Symposium..

[16]. Zhu, C.Yuan, Y.Chen, Z. Meng, C. and Wang, S. (2020). Study of the Stability Control of Rock Surrounding Longwall Recovery Roadways in Shallow Seams. Shock and Vibration.

[17]. Hudson, JA. (1992). Rock engineering systems: theory and practice. Ellis Harwood Ltd.

[18]. Benardos, A.G. and Kaliampakos, D.C. (2004). A methodology for assessing geotechnical hazards for

TBM tunneling-illustrated by the Athens Metro, Greece. Int J Rock Mech Min Sci 41: 987–999.

[19]. Hosseini, A. Najafi, M. and Morshedy, A. H. 2022. "Determination of suitable distance between methane drainage stations in Tabas mechanized coal mine (Iran) based on theoretical calculations and field investigation," Journal of Mining Institute, Vol. 258, pp. 1050-1060, 2022.

[20]. Hosseini, A. Najafi, M. and Hossein morshedy., A. 2022. "The effect of technical parameters of cross-measure boreholes methane drainage method on the amount of exhaust gas (Case study: Tabas Parvadeh coal mine No.1)," Journal of Analytical and Numerical Methods in Mining Engineering.

پیش بینی شکست سقف در ورودهای اولیه کارگاه استخراج و انتخاب نوع مناسب روش اتاق بازیابی تجهیزات در روش جبهه‌کار طولانی

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چکیده:

در این مطالعه، دو مدل مبتنی بر سیستم مهندسی سنگ (RES) برای پیش‌بینی شرایط پایداری و نوع روش بازیابی تجهیزات در معدنکاری جبهه‌کار طولانی ارائه شده است. مدل اول، شکست سقف هنگام پیشروی یک کارگاه جبهه‌کار طولانی به سمت اتاق بازیابی (RR) را پیش بینی می‌کند و مدل دوم جهت انتخاب نوع روش و اتاق بازیابی تجهیزات جبهه‌کار طولانی را با کم‌ترین ریسک پایداری ارائه شده است. در ارتباط با مدل ۱، پایگاه داده‌ای با ۴۳ مورد مطالعاتی از اتاق‌های بازیابی در نظر گرفته ه است که شامل پارامترهای فنی و نوع خروجی عملیات بازیابی از لحاظ وضعیت پایداری (موفق، وقوع شکست نوع ریزش سقف، یا وقوع شکست نوع وزنی) می‌باشد. در این بخش، یک اندیس ریسک (VI) جهت تخمین شکست سقف برای هر مورد مطالعاتی در نظر گرفته شد و نتایج با خروجی‌های هر عملیات مقایسه گردید. نتایج بدست آمده نشان داده است که مقادیر VI بدست آمده همبستگی خوبی با خروجی‌های متناظر آن دارد. این روش می‌تواند برای آنالیز ریسک شکست سقف در اتاق‌های بازیابی مورد استفاده قرار گیرد و مقدار VI بحرانی را برای مشخص نمودن مرز بین دامنه خطر و دامنه شرایط عملیات ایمن جهت برنامه‌ریزی دقیق تعیین کند. در ادامه، مدل ۲ تحت عنوان مدل چند گزینه‌ای یا چند هدفی مبتنی بر RES (MORESM) برای انتخاب روش اتاق بازیابی ارائه گردید. انتخاب یک گزینه/هدف از بین چند گزینه یا هدف در شرایط وجود پارامترهای موثر متعدد در یک سیستم توسط مدل ۲ امکان پذیر است. مدل ارائه شده می‌تواند یک ابزار مناسب برای لحاظ تمامی شرایط تأثیرگذار بر روی انتخاب بهینه نوع روش بازیابی جهت انتقال تجهیزات روش جبهه‌کار طولانی از سینه‌کار فراهم کند.

کلمات کلیدی: اتاق بازیابی، ورودیهای پیش حفرشده، جبهه کار طولانی، سیستم های مهندسی سنگ، مدل مبتنی بر RES چند گزینه ای (MORESM)