JME

Journal of Mining & Environment,
Vol. 9, No. 3, 2018, 605-621.
DOI: 10.22044/jme.2018.6649.1486

Determination and assessment of coal bed methane potential using rock engineering systems

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Received 15 January 2018; received in revised form 1 March 2018; accepted 6 March 2018
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Abstract

The presence of methane in coal mines is one of the major problems in underground coal mines. Every year, in underground coal mines, a lot of casualties due to outbursts and explosions of methane gas is occurring. Existence of this gas in the mines not only creates a difficult and dangerous situation for work but also makes it more expensive. The release of this gas to the air causes a further pollution of the atmosphere and increases the greenhouse gases in the air. Thus Coal Bed Methane (CBM) drainage before, during, and after coal mining is necessary. Accordingly, the CBM drainage can reduce the risks involved in these mines. In the past decade, CBM has offered a significant potential to meet the ever-growing energy demand and can decrease the disastrous events. In this research work, the CBM potential in Eastern Kelariz, Western Razmja, Bornaky, Bozorg, Razzi, and Takht coal mines of Eastern Alborz coal mines company is investigated using the rock engineering systems (RES) based on the intrinsic and geological parameters. Nine main parameters are considered for modeling CBM, and the interactions between these parameters are calculated by a proposed system. Based on the RES method, the parameters that are dominant (depth of cover) or subordinate (gas content) and also the parameters that are interactive are introduced. The proposed approach could be a simple but efficient tool in the evaluation of the parameters affecting CBM, and hence be useful in decision-making. The results obtained show that Razzi coal mine has a good potential to perform CBM drainage.

Keywords: *Coal Bed Methane (CBM), Rock Engineering Systems (RES), Eastern Alborz Coal Mines.*

1. Introduction

Fossil fuels contain nearly 90% of the proved reserves of global energy. Today, coal is the major component and most plentiful and economical fossil fuel including nearly 90% of the fossil fuel energy around the world. Over the past 250 years, it has played a vital and fundamental role in the development and stability of the world economy [1].

Coal mining is a very intricate system and process. The rough working conditions and the hazardous environment are the most important factors that affect a coal mining process. The hazards of underground mining are critical factors that should be considered in the design and planning steps of coal mines [2]. One of these hazards that can damage a mine is methane gas. Methane gas is one of the energy carriers that exist in coal [3].

Coal bed methane (CBM) is a potentially important energy resource in many major coal mining countries of the world. CBM, as the name implies, is a gas contained in coal beds that are usually not commercially viable for mining. The methane gas existing in coal is of low-carbon energy and clean burning source, which can be used as fuel for use in residential, industrial, commercial, electricity generation, and fuel vehicles [3].

Methane is the major component of CBM, accounting for 80-95%. The balance is made up of ethane, propane, butane, carbon dioxide, hydrogen, oxygen, and argon. Coal seams are, therefore, both a source and a reservoir for CBM [4].

CBM reservoirs are different from conventional reservoirs in a number of ways but the primary differences are water production and gas-storage mechanism. Hydrocarbon-storage capacity in most oil and gas reservoirs is related to porosity because gas is trapped and stored in the pore systems of the matrix. Coals have a moderate intrinsic porosity, yet they can store up to six times more gas than an equivalent volume of sandstone at a similar pressure. Gas-storage capacity is determined primarily by a coal's rank. Higher rank coals-bituminous and anthracite-have the greatest potential for methane storage [5].

CBM is considered as an unconventional gas because it is both a source rock and a reservoir rock of how the gas is stored and the manner in which the gas is produced. Coals generate and contain the gas internally, conventional reservoir host gas sourced from other formations that migrate to the reservoir.

Methane is the most dangerous gas included in the atmosphere of underground coal mines due to the explosion risk. It is present in coal deposits as well as in sterile rocks from the proximity of coal beds. Thus mine atmosphere is very important for correct functioning of the ventilation and gasification systems [6].

Trapped in the middle of coal is an unconventional natural gas whose vast untapped resource is still at a very aborning stage. CBM was bane for mining from the very beginning. As coal is mined, methane is released into the mine air. Methane becomes explosive when mixed with air in the range 4.5-15% by volume. The history of coal mining around the world is replete with mine disasters when the methane-air mixture exploded.

After a couple of outbursts and explosions of methane gas from various coalfields, the industry was quick to acknowledge that this gas could be used as fuel and so CBM was born. With abundant coal reserves around the globe coupled with depletion of the conventional source of energy such as fossil fuels, and increasing events such as outbursts and explosions of methane gas in coal mines, CBM has offered a significant potential to meet the ever-growing energy demand and can decrease the disastrous events.

Efforts to mitigate this disaster started via gob gas drainage with cross-measure boreholes but serious efforts to degas the coal seam prior to mining and post-mining began in the 1970s. The coal industry made the mines a safer place to work and boosted the productivity as well. Thus it would be no exaggeration to say that CBM, which is a bane to mining industry, has now become a boon and has a lot of advantages-a viable source of additional energy. It is clear now that these new technologies can open-up the vast coal reserve for gas production.

Thus CBM drainage is used to promote mine safety and increase energy supply by producing methane from coal seams. In this work, the determination and assessment of CBM potential in Eastern Kelariz, Western Razmja, Bornaky, Bozorg, Razzi, and Takht coal mines of Eastern Alborz Coal Mines Company was carried out.

The previous methods that were based upon the survey data from various in situ test methods in a certain range of coal types could not be generalized for various ground conditions. Furthermore, all the previous methods do not simultaneously consider all the pertinent parameters in modeling, and high gas-storage capacity is not required for successful commercial operations [5]. Under such limitations or constraints, estimation of the CBM potential requires innovative methods such as the RES-based model, capable of accounting for unlimited parameters in the model. Achievement along by concerning RES application showed the good performance of RES in rock engineering fields. In this work, the RES-based model, capable of determination of many intrinsic and geological parameters in the model, was used to carry out an estimate of the CBM potential of the Eastern Alborz coal mines in Iran.

2. Rock engineering systems (RES)

One of the most powerful approaches followed to solve complex engineering problems is the rock engineering systems (RES). RES is an interaction matrix (IM) technique and a multi-objective system introduced by Hudson in 1992 [7] (see also Jiao and Hudson, 1995 [8], 1998 [9]). This method is a methodology capable of the simultaneous analysis of the relations between the effective parameters to deal with complex engineering problems from a holistic viewpoint with its preferential characteristics such as comprehensiveness, adaptability, repeatability, efficiency, and effectiveness [8-10].

The RES approach has been widely applied to various engineering problems, for example, hazard and risk assessment of rockfall [11], evaluation of the stability of tunnels and underground excavations [12-16], analysis of blasting and blast ability in rock masses [17-19], rock mass characterization for indicating natural slope instability [20-37], environmental studies on the disposal of spent fuel [38], river catchment pollution [39], radioactive waste management [40, 41], forest ecosystems [42, 43], traffic-induced air pollution [44], assessment of geotechnical hazards for tunnel boring machine (TBM) tunneling [45], risk of reservoir pollution [46], quantitative hazard assessment for tunnel collapses [47], evaluation and classification of the spontaneous coal combustion potential [48], estimation of back break in bench blasting [49], prediction of rock fragmentation by blasting [50, 51], development of a rock groutability index [52], estimating TBM downtimes [53], prediction of flyrock distance in surface blasting [54], prediction of out-of-seam dilution in longwall mining [55], prediction of the advance rate in rock TBM tunneling [56], rock mass cavability in block caving mines [57-60], risk assessment and estimation of TBM penetration rate [61], estimation of the rock mass deformation modulus [62], rock mass classifications to carbonate rocks for engineering purposes [63], predicting wear performance of circular diamond saw in hard rock cutting process [64], and estimation of the required rotational torque to operate horizontal directional drilling [65].

The approach is inspired to the general theory of the systems by von Bertalanffy (1950 [66], 1968 [67]), according to which a system is defined as “a complex of elements in interaction”, and later by Hall and Fagen (1956) [68], according to which a system is “a set of objects together with the relations between the objects and their attributes”, where the objects are the components or parts of the system, the attributes are the properties of the objects, and the relationships “tie the systems together” [63]. The factors and variables involved in a rock engineering project may have a certain effect on other factors and the whole system, and contrariwise, may be affected by other factors to a certain scope. The essence of this approach is that all potentially relevant variables ought to be considered [8].

In RES application, the interaction matrix device [7] is the basic analytical tool and a presentational technique for characterizing the important parameters and the interaction mechanisms in a rock engineering systems. In the interaction matrix for a given rock engineering systems, all the parameters influencing the system are arranged along the leading diagonal of the matrix called the diagonal terms. The influence of each individual factor on any other factor is accounted for at the corresponding off-diagonal position, named the off-diagonal terms. The off-diagonal terms are assigned numerical values that describe the influence degree of one factor on the other factors. Assigning these values is called coding the matrix.

Several coding methods developed for this purpose such as the 0-1 binary method, expert semi-quantitative (ESQ) method, explicit method, continuous quantitative coding (CQC), and probabilistic expert semi-quantitative (PESQ) method have been proposed for numerically coding the interaction matrix.

The most common coding method is the “expert semi-quantitative” (ESQ). ESQ coding has been used in nearly all the previous works cited above. In this method, one unique code is deterministically assigned to each interaction, thereby expressing the effect of a parameter on another in the matrix. Typically, coding values vary between 0 and 4, with 0 indicating no interaction and 4 indicating the hyper-level of interaction or “critical interaction” (Table 1).

The general concept of the influences in a system is described by the interaction matrix, which is shown in Figures 1 and 2. Here, the influence of ‘‘A’’ on ‘‘B’’ is not the same as that of ‘‘B’’ on ‘‘A’’, which means that the matrix is asymmetric [10]. Thus it is important to put the parameter interactions in a clockwise direction in the matrix. In the interaction matrix, the sum of a row is called the ‘‘Cause’’ value ($C_{pi} = \sum_{j=1}^{n} I_{ij}$) and the sum of a column is the ‘‘Effect’’ value ($E_{pj} = \sum_{i=1}^{n} I_{ij}$), denoted as coordinates (C, E) for a particular parameter. The coordinate values for each parameter can be plotted in cause and effect space, forming the so-called C–E plot. The interactive intensity value of each parameter is denoted as the sum of the C and E values (C+E), and it can be used as an indicator of parameters' significance in the system. That is, the weight for parameter i, indicated by a_i (Equation 1), is given by its ‘‘parameter interaction intensity’’ ($C_i + E_i$) divided by the (total) sum of interaction intensities of all parameters in the system [7].

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

where
i is the number of main parameters;
C_i is the cause (impressments) of each parameter in system;
E_i is the effect (unaffected) of each parameter in system;
$\sum_{i=1}^{n} C_i$ is the sum of C_i in the whole system;
$\sum_{i=1}^{n} E_i$ is the sum of E_i in the whole system;
a_i is the weighting of each parameter (%).

Table 1. ESQ method for interaction matrix coding [7, 21].

Code value	Description
0	No interaction
1	Weak interaction
2	Medium interaction
3	Strong interaction
4	Critical interaction

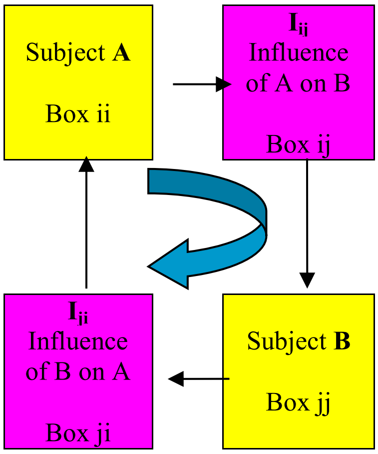

Figure 1. Principle of interaction matrix [7].

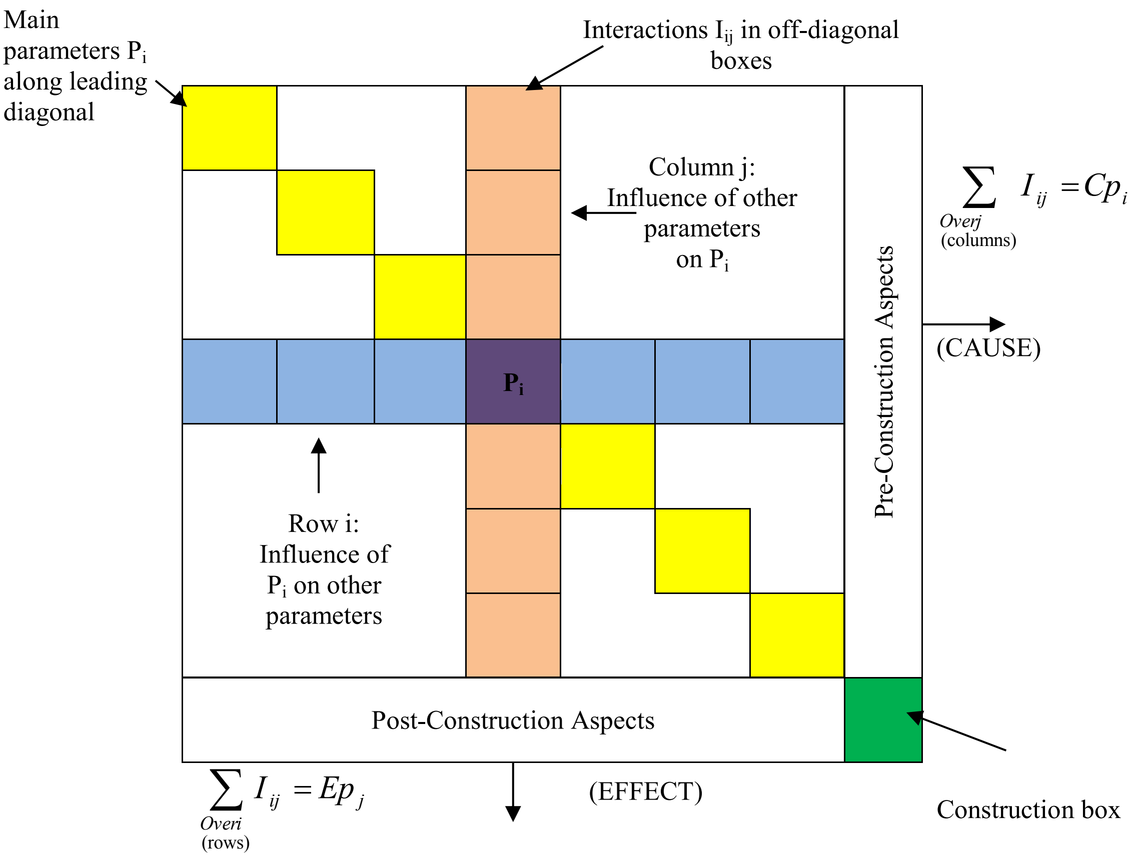

Figure 2. Summation of coding values in the row and column through each parameter to establish the cause and effect of coordinates [10].

3. Methodology

3.1. Development of RES model application for classification of CBM potential

In order to define the model, four main steps must be taken into account, as follow:

3.1.1. Selecting most important parameters

In the first step, identification of the parameters responsible for the CBM potential is necessary. According to the available literature and studies on the CBM subject, a total of nine major parameters for CBM potential were identified and categorized (Figure 3).

3.1.2. Interaction matrix

In the second step, analyze their behavior and evaluate the significance (weight) that each one has in the overall risk conditions as interaction matrix formation or coding matrix. In this step, the RES principles can be used to assess the weighting of the parameters involved. The factors contributing to the CBM potential were assigned weights using the RES and ESQ coding methods (Table 1).

The nine principal parameters influencing the CBM potential are located along the leading diagonal of the matrix, and the effects of each individual parameter on any other parameter (interactions) are placed on the off-diagonal cells. The values assigned to off-diagonal cells are called coding the matrix. Table 2 provides the matrix. Table 3 gives cause (C), effect (E), interactive intensity (C+E), dominance (C–E), and weight of each (a_i). As shown in Table 3, depth of cover (P_7) has the highest weight in the system and tightly controls the other elements.

The choice of considering the summation C+E as a discriminating factor among the parameters is made to emphasize the role of the system interactivity. On average, the more a system is interactive, the more it is potentially unstable since there is more chance of a small variation in one parameter significantly affecting the system behavior [7].

The effect-cause histogram, C+E (interaction intensity), C-E, C-E/C+E, a (%) for each parameter is illustrated in Figures 4-8, respectively.

In Figure 4, the diameter of this graph represents the locus of C=E line. Along this line, the value for (C+E) increases. If the parameter has a large value of (C-E), it is located in the bottom right portion of the diagram, and it is ''dominant'' on the system. The parameters affected by the system are located in the top left corner of the diagram and have the smaller values for (C-E). The cause-effect plot is a helpful tool in understanding the behavior of each factor individually as well as studying the whole system.

It is clear in Figure 4 that for some parameters, position in the (C, E) plot tends to assume positions further away from the diagonal line with equation C=E, and therefore, indicating that they have high dominance on the system (when the location of the parameter is on the lower right region; see, e.g. P7 in Figure 4); that the system has a dominance on them (when the location of the parameter is on the upper left region; see, e.g. P6 in Figure 4); or that they are ''neutral'' with respect to the system (when the location of the parameter is mainly on the C=E line; see, e.g. P5 in Figure 4).

Due to the importance of system interaction, the sum of cause and effect value is selected as the distinguishing factor between parameters. Generally, when the value for interaction of a system is large, the system is potentially unstable. In other words, there is a greater chance that a small change in a parameter greatly affects the system's behavior [7].

By obtaining the sum and the difference of the causes and effects (C+E, C-E) for each parameter, the interaction intensity histogram for each parameter can be plotted (Figures 5 and 6). It is clear from the histogram of the interactive intensity versus the parameters (Figure 5) that the intensity for the majority of the parameters is slightly above the mean value. From all the above, it can be concluded that the nine parameters selected to be the principal ones and acting as a combined set of assessment criteria are all passing the ''importance threshold''. Also the interaction intensity histogram shows that exist of tectonic faults in seam (P3), gas content (P6), and depth of cover (P7) have the largest interaction in the system, and this means that a little change in these parameters has a significant effect on the system's behavior. It can also be concluded from the C–E histogram (Figure 6) that the parameter P7 (depth of cover), which has the maximum value for C–E, dominates the system.

From the C-E/C+E plot (Figure 7), it can also be concluded that the parameter P7 (depth of cover) has a high dominance on the system and P6 (gas content) is subordinate on the system and the system has a dominance on P6.

In addition, based on the cause-effect diagrams of the nine parameters considered in the presented

CBM potential analysis (Figures 4, 5, 6, and 7), the following remarks can be made:

- The most interactive parameters are exist of tectonic faults in seam (P3), gas content (P6), and depth of cover (P7), which have the maximum value for C+E.
- The less interactive is the water flow (moisture) (P2), which has the minimum value for C+E.
- The depth of cover (P7) is the one that dominates the system since it has the maximum value for C-E.
- The gas content (P6) that has the minimum value for C-E is most dominated by the system.

The results obtained show that all the nine ‘‘input’’ parameters are rather interactive and have a significant influence on the ‘‘outcome’’ parameter (i.e. CBM potential); therefore, they should be taken into account in the engineering decisions.

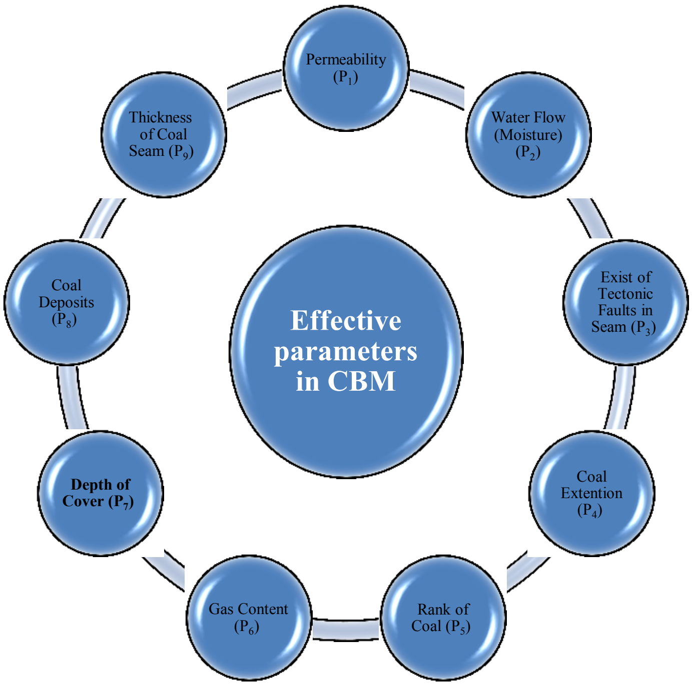

Figure 3. Important characteristics influencing CBM potential to define the RES-based model.

Table 2. The interaction matrix for parameters influencing CBM potential.

									Cause (C)
P_1	3	0	0	0	3	0	0	0	**6**
1	P_2	0	0	0	0	0	0	0	**1**
3	3	P_3	3	2	4	0	3	3	**21**
1	2	2	P_4	1	3	1	4	0	**14**
4	0	0	0	P_5	4	0	0	0	**8**
0	0	0	0	0	P_6	0	0	0	**0**
4	3	2	2	4	4	P_7	3	3	**25**
0	0	0	2	0	4	0	P_8	0	**6**
3	0	0	0	0	3	0	۳	P_9	**9**
16	**11**	**4**	**7**	**7**	**25**	**1**	**13**	**6**	

Effect (E)

Table 3. Weighting of the main parameters in CBM potential.

Parameters	C	E	C+E	C-E	a_i (%)
P_1	6	16	22	-10	12.22
P_2	1	11	12	-10	6.67
P_3	21	4	25	17	13.89
P_4	14	7	21	7	11.67
P_5	8	7	15	1	8.33
P_6	0	25	25	-25	13.89
P_7	25	1	26	24	14.44
P_8	6	13	19	-7	10.56
P_9	9	6	15	3	8.33
	$\sum_{i=1}^{9} C_i = 90$	$\sum_{i=1}^{9} E_i = 90$	$\sum_{i=1}^{9} (C_i + E_i) = 180$	$\sum_{i=1}^{9} (C_i - E_i) = 0$	$\sum_{i=1}^{9} a_i = 100$

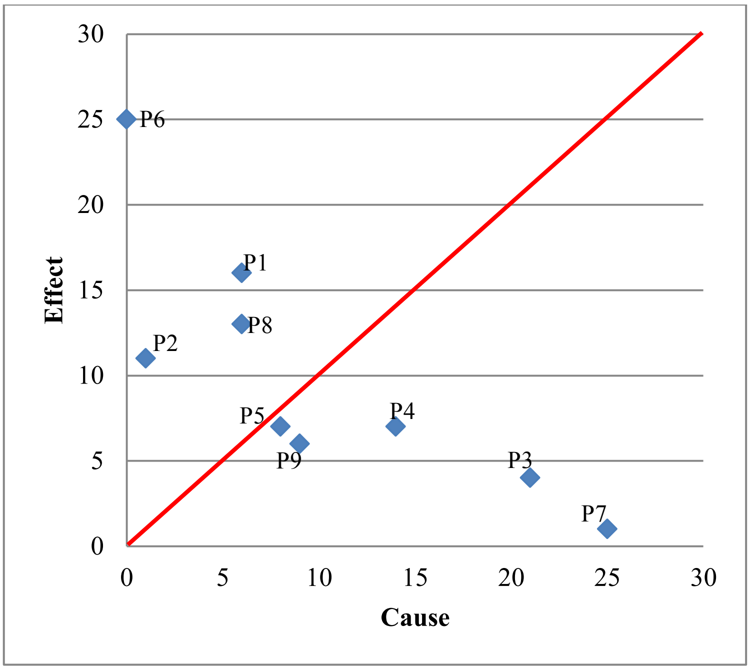

Figure 4. The cause-effect (C-E) plot for principal parameters of CBM potential.

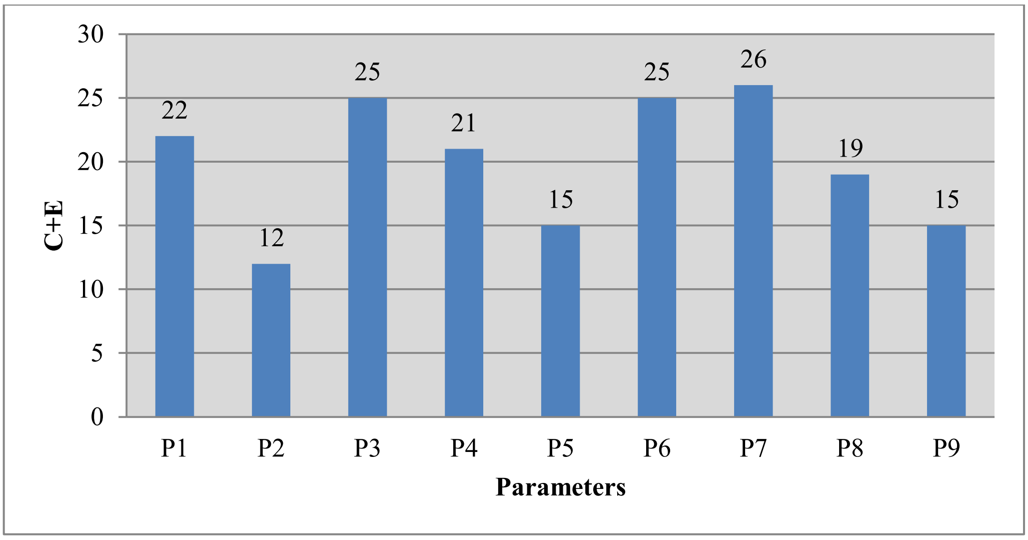

Figure 5. Interaction intensity for the parameters in considered system.

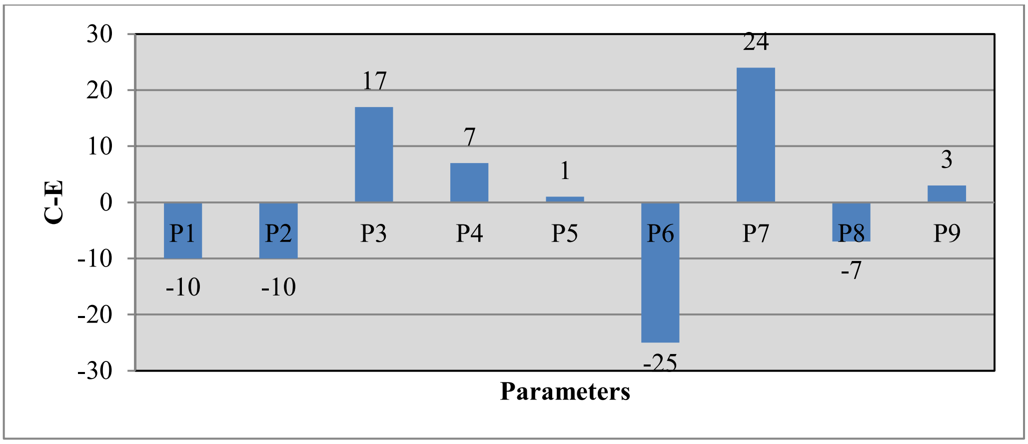

Figure 6. Values of the difference of the causes and effects for each parameter.

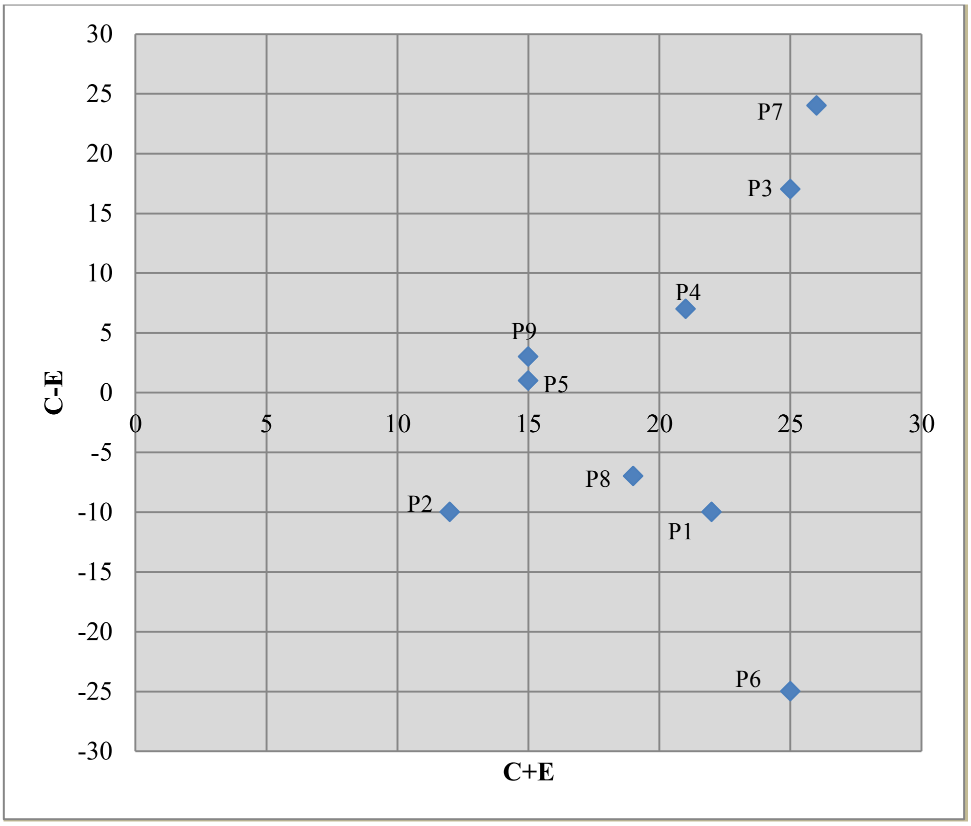

Figure 7. The C–E/C+E plot for values of Causes and Effects.

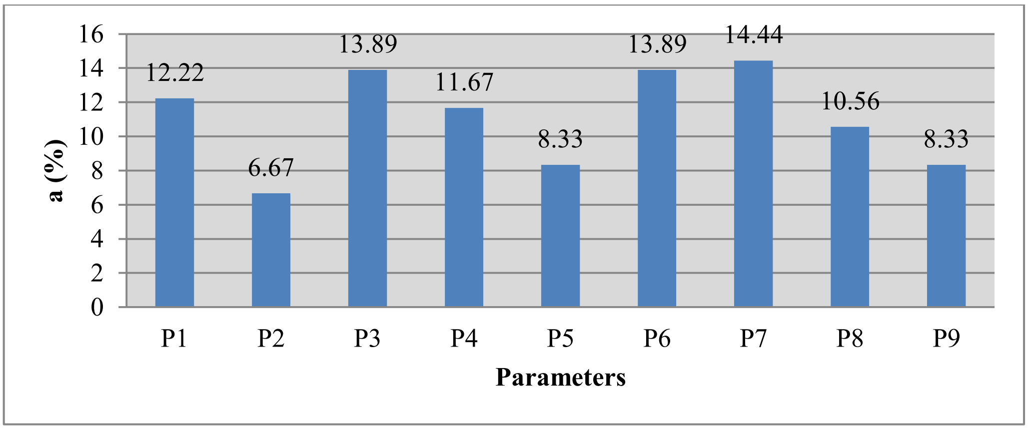

Figure 8. Weighting of the parameters in CBM potential.

3.1.3. Rating of parameters

In the third step, the rating of the parameter values was carried out based upon their effect on the CBM potential. Six classes of rating, from 0 to 5, were considered; with 0 indicating the worst position (most unfavorable condition) and 5 that indicates the best state (most favorable condition). In the case of CBM potential, the rating of each parameter is presented in Table 4. The ranges of parameters in Table 4 were proposed based on the results obtained by available literature and studies on the CBM subject.

Table 4. Proposed ranges and rating for effective parameters in CBM potential.

Parameters (Unit)	Suggested ranges and rating					
	0	1	2	3	4	5
Permeability (mD)	<0.1	0.1-1	1-3	3-10	10-30	>30
Water Flow (Moisture, %)	>24	12-24	7-12	5-7	3-5	<3
Exist of Tectonic Faults in Seam	Big fault with great failures	More than 2 small fault /500 m	Less than 2 small fault/500 m	Not available	---	---
Coal Extension	Low	Medium	High	---	---	
Rank of Coal	Lignite	Sub-bituminous	Anthracite	Bituminous	---	---
Gas Content (m^3/ ton)	<5	5-10	10-15	>15	---	---
Depth of Cover (m)	<50 >1250	1000-1250	750-1000	500-750	250-500	50-250
Coal Deposits (M.ton)	0-0.5	0.5-1	1-2	2-3	3-4	>4
Thickness of Coal Seam (m)	<1.2	1.2-2.4	2.4-3.2	3.2-5	>5	---

3.1.4. CBMPi and vulnerability index ranges

In the fourth step, rating of Coal Bed Methane Potential index (CBMPi) for each mine can be calculated according to Equation 2 (modified after [7]).

$$CBMPi_j = \sum_{i=1}^{9} a_i \frac{P_{ij}}{P_{Max_i}} \tag{2}$$

where

i refers to parameters (1 to 9)

j refers to the number of mines

a_i is the weighting of each parameter (%) (obtained from Equation 1).

P_{ij} is the rating assigned to different classes of parameter i values, and is different for different mines j.

P_{Maxi} is the maximum value rating of parameter i; it is for normalization by dividing with the maximum rating.

$CBMPi_j$ is the Coal Bed Methane Potential index of each mine; the maximum value of the index is 100, which refers to the most favorable conditions for CBM potential and the minimum index is 0, which refers to the most unfavorable conditions for the CBM potential.

Vulnerability index is in a range of 100 points that can be divided into three or five areas. In this range, a higher point indicates a higher CBM potential of condition (modified after [21]). In this work, a three-area classification system based on CBMPi with low, medium, and high CBM potentials was used (Table 5).

Table 5. Classification of CBMPi.

Category	Low	Medium	High
	I	II	III
CBMPi	0≤CBMPi<33	33≤CBMPi<66	66≤CBMPi<100

3.2. Case study: Eastern Alborz Coal Mines Company, NE Iran

The Eastern Alborz coal field is located in the Alborz Mountains (Figure 9). The Eastern Alborz coal mines are the most important productive coal mines in the Eastern Alborz Mountains. The region varies in elevation from 2000 to 2800 m above the sea level. Eastern Alborz coal mines include two major mining areas, Tazareh and Olang-Qeslaq.

In the Eastern Alborz Mountains, most of the Shemshak Formation appears to be Early Jurassic in age. The Upper Triassic-Lower Jurassic Shemshak Formation [69] is an up to 4,000 m thick package of siliciclastic sediments occurring over large areas of the Iran Plate, in particular, central-eastern Iran and the Alborz Mountains.

There, the Shemshak Formation overlies, with sharp and disconformable contact, the limestones and dolomites of the Elikah Formation (Lower-Middle Triassic), and is followed disconformably by the marls and limestones of the Dalichai Formation (Figure 10) [70, 71].

Tazareh section is one of the thickest developments of the Shemshak Formation in the Alborz range. The Shemshak Formation at Tazareh is a nearly exclusively siliciclastic succession, representing a range of environments, from fluvial and lacustrine to coastal and fully marine. The upper 1600 m of the section is fully marine, containing a low to moderately diverse benthic macrofauna. Ammonites occur at several levels, and indicate that the marine phase range from the Middle Toarcian to the Upper Aalenian [70, 71].

In Figure 11, the stratigraphic column of the upper part of Shemshak Formation in Eastern Alborz and distribution of coal seams in Tazareh Mine is shown.

In order to classify the CBM potential fields of Eastern Alborz coal mines using the RES approach, the Eastern Kelariz, Western Razmja, Bornaky, Bozorg, Razzi, and Takht coal mines were selected.

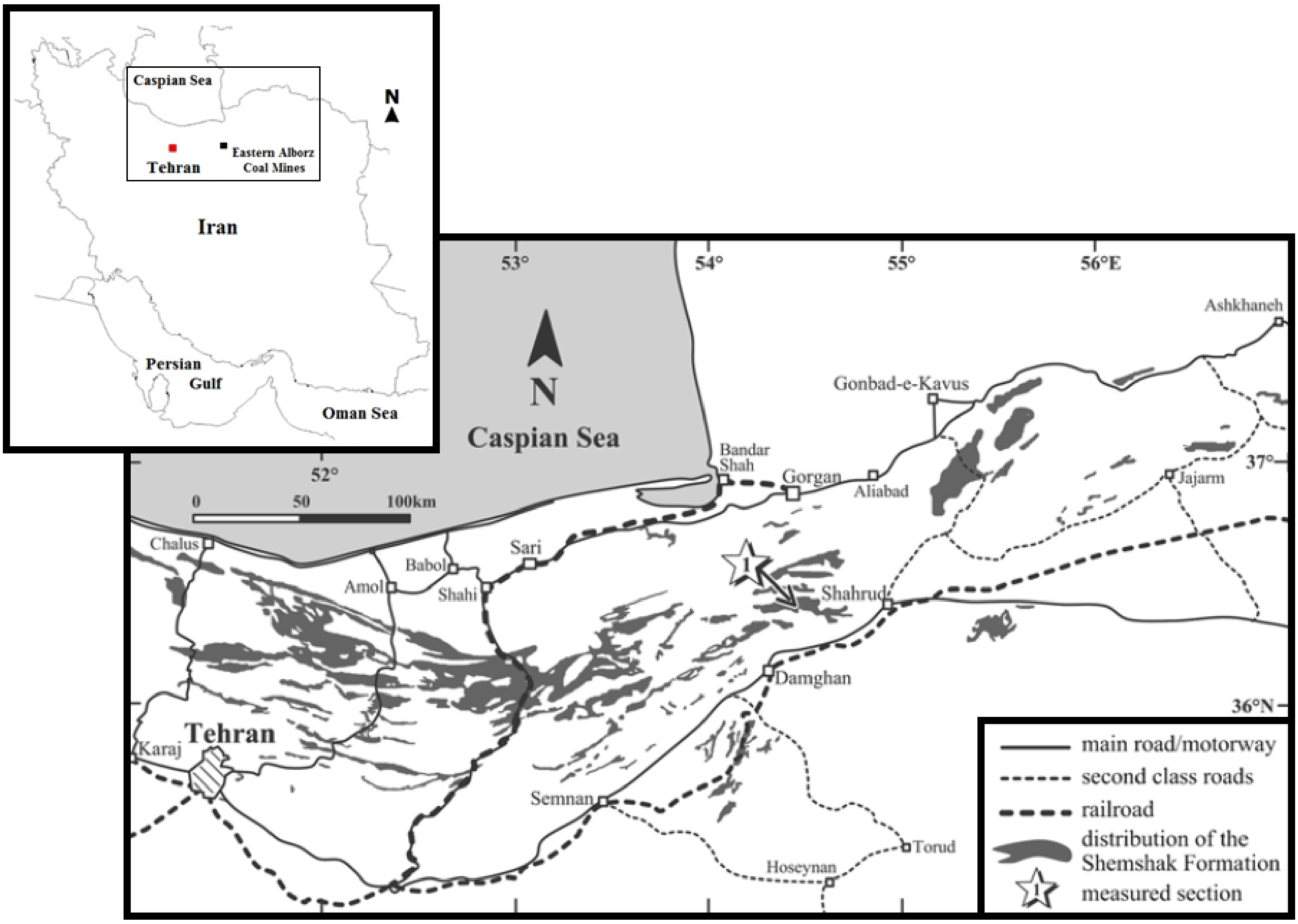

Figure 9. Locality map with distribution of Shemshak Formation in the central and eastern Alborz Mountains, Iran [72].

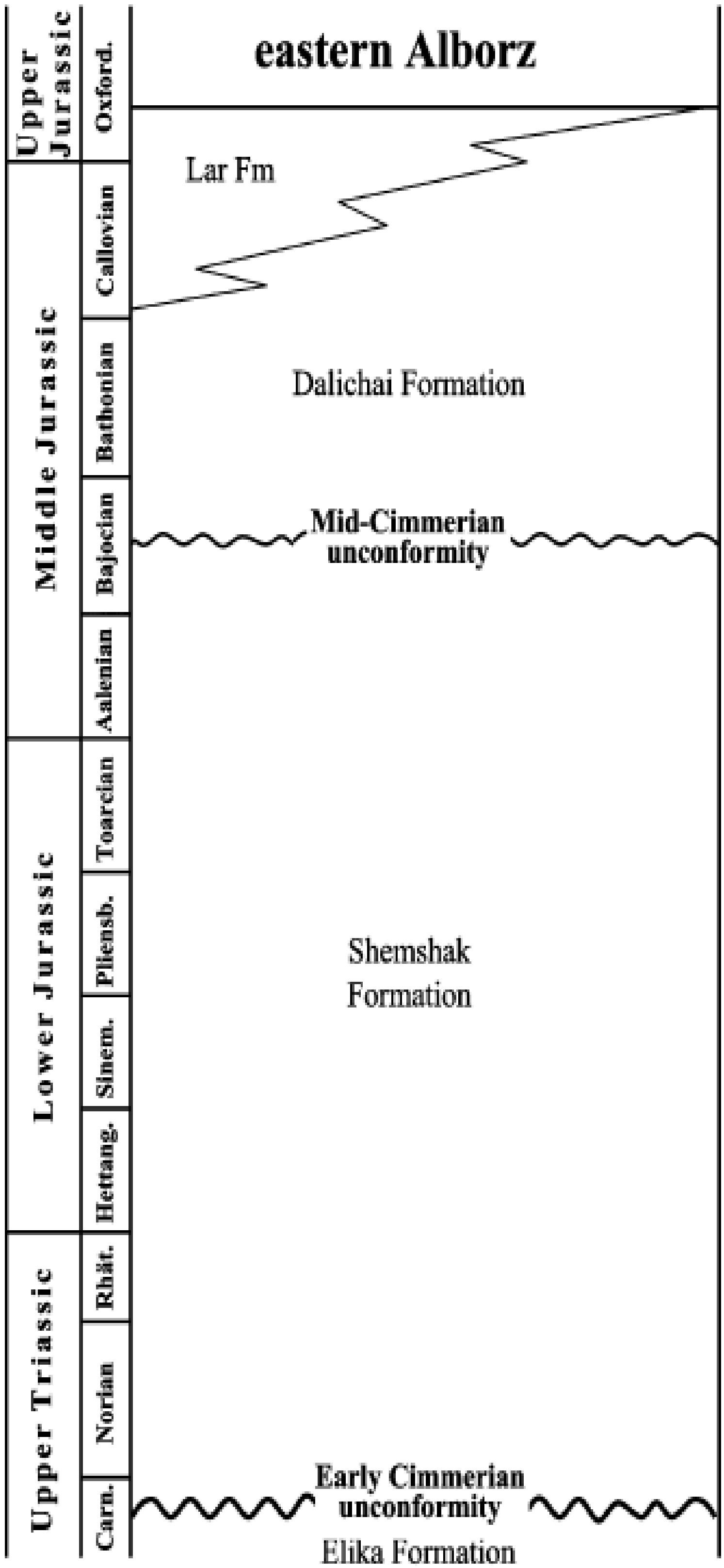

Figure 10. Upper Triassic to Upper Jurassic lithostratigraphic units in Eastern Alborz Mountains [70, 71].

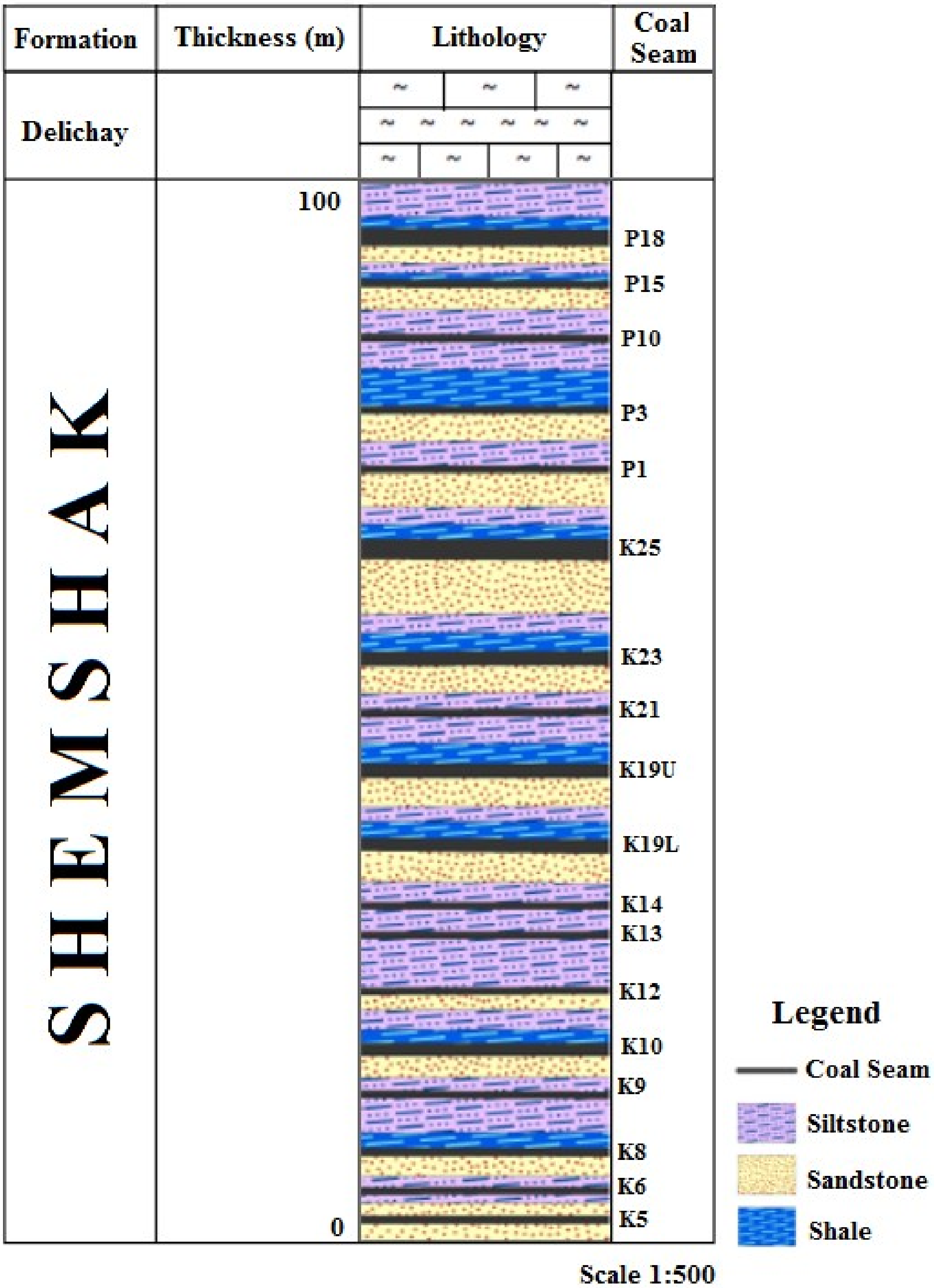

Figure 11. Stratigraphic column of upper part of Shemshak Formation in Eastern Alborz and distribution of coal seams in Tazareh mine [72].

4. Results

Each mine should be rated by calculating CBMPi. The rating of each mine is presented in Table 6. After calculating CBMPi for each mine, we can classify each mine according to the value ranges presented in Table 5. The proposed classification is given in Table 6 (End Column). The results obtained show that the Razzi coal mine has a high potential for CBM.

It bears noting that the presented classification and indexing should be validated by the events that occurred in the past. Comparison of the results between classification and the events that occurred in the past demonstrate a good concordance. Existence of methane gas in the Razzi coal mine not only created a dangerous situation for work but also mining in this mine has been stopped. Thus the Razzi coal mine has a good potential to perform CBM. In this way, the disastrous events can be decreased and energy can be used.

This suggests that the use of a systematic approach in analyzing the CBM potential in a large scale and in the issues of multiple factors can be very useful.

Table 6. Calculation of CBMPi for Eastern Alborz Coal Mines Company.

	Rating of parameters										CBMPi
Weight of each parameter	12.22	6.67	13.89	11.67	8.33	13.89	14.44	10.56	8.33	$\sum_{i=1}^{9} a_i = 100$	
P_{Maxi}	5	5	3	2	3	3	5	5	4	---	
Parameters / **Mines**	P1	P2	P3	P4	P5	P6	P7	P8	P9	CBMPi	
Eastern Kelariz	1	5	1	2	2	2	3	2	1	55.20	Medium
Western Razmja	1	5	1	2	2	2	3	3	1	57.31	Medium
Bornaky	1	5	2	2	2	2	3	2	1	59.83	Medium
Bozorg	1	5	1	1	2	2	3	3	1	51.47	Medium
Razzi	1	4	2	2	3	3	3	3	2	70.10	High
Takht	1	4	2	2	2	1	3	5	1	60.20	Medium

5. Conclusions

The increase in energy demand and the rapid decrease in energy resources in the world have led to the production of energy from unconventional hydrocarbon reservoirs such as coal reserves that are economically affordable. Coal is a main source of energy in the world that has been used for centuries. Methane is the most dangerous gas included in the atmosphere of underground coal mines due to the explosion risk. Existence of this gas in coal mines not only creates a difficult and dangerous situation for work but also makes it more expensive; the need of miners to mine ventilation and release of the gas in the atmosphere are incurred at extra costs. The release of this gas into the air also causes further pollution of the atmosphere, and increases the greenhouse gases in the air. In the past decade, CBM has offered a significant potential to meet the ever-growing energy demand and can decrease the disastrous events.

CBM is a potentially important energy resource in many of the major coal mining countries of the world. Significant volumes of CBM are exploited worldwide with most of the gas originating from operational deep coal mines, and lesser quantities are recovered from abandoned mine workings. Many coal-producing countries are now looking at the potential for a wider application of CBM technologies to maximize the exploitation of gas from coal seams. CBM is a clean fuel with similar properties to natural gas when not diluted by air or other non-combustible mine gases.

In Iran, there are many coal reservoirs that can be expected to be capable of CBM. On the other hand, due to the growing trend and increase in the country's energy needs and importance of finding a replacement for conventional oil and gas resources, the feasibility of CBM potential in coal reservoirs is necessary. By using CBM before, during, and after coal mining, the existence of dangers in coal mines can be decreased. In this research work, the CBM potential in the Eastern Alborz Coal Mines Company was studied and a new CBM potential index (CBMPI) was presented to assess the CBM potential.

Many parameters influence CBM in coal mines. Understanding the influence and importance of these parameters has an important role in investigating and predicting the CBM potential. The approach applies the rock engineering systems (RES) method to account for the intricate interactions that exist between the parameters involved in real projects. In this way, nine parameters affecting CBM were selected; then the RES interaction matrix was coded using expert semi-quantitative (ESQ). The results obtained from cause-effect diagram show that depth of cover (P7) is the most interactive parameter. In other words, a small change in this parameter causes a large change in the system. Similarly, "Gas Content" (P_6), "Permeability" (P_1), "Water Flow" (P_2), and "Coal Deposits" (P_8) are also quite significant parameters. Such information has an important practical use, and, for instance, has implications on site characterization since it allows a designer to identify the parameters that should be characterized in more detail in any particular case. The new index was used to rank the CBM potential of the Eastern Alborz Coal Mines Company, and the results obtained showed that the Razzi coal mine had a good potential to perform CBM.

Since in the system analysis (e.g. RES method), all the parameter interactions could be simultaneously considered, these methods have the ability to solve complex problems. The new proposed index (CBMPI) based on the system analysis provides a reliable result in the CBM potential assessment. Comparing the results of this classification and the events occurring in each class in the past times indicate a relatively good concordance.

Acknowledgments
The authors wish to thanks the Eastern Alborz Coal Mines Company management for their appreciable cooperation and support.

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ارزیابی و تعیین قابلیت گاز زدایی متان با استفاده از روش سیستم‌های مهندسی سنگ

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ارسال ۲۰۱۸/۱/۱۵، پذیرش ۲۰۱۸/۳/۶

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چکیده:

حضور گاز متان در معادن زغال‌سنگ یکی از مهم‌ترین مشکلات عمده در معادن زیرزمینی زغال‌سنگ است. هر ساله، در معادن زیرزمینی زغال‌سنگ تلفات زیادی ناشی از انفجار گاز زغال‌سنگ رخ می‌دهد. حضور این گاز در معادن نه تنها باعث ایجاد شرایط سخت و خطرناک کاری می‌شود، بلکه آن را پرهزینه‌تر نیز می‌سازد. رهاسازی این گاز در هوا باعث آلودگی بیشتر اتمسفر و افزایش گازهای گلخانه‌ای در هوا می‌شود؛ بنابراین گاز زدایی قبل، در حین و بعد از استخراج لازم به نظر می‌رسد. بر این اساس با گاز زدایی متان می‌توان میزان خطرهای موجود در این معادن را کاهش داد. در دهه‌های اخیر گاز زدایی از معادن زغال‌سنگ پتانسیل قابل ملاحظه‌ای برای پاسخگویی به تقاضای در حال رشد انرژی را فراهم کرده است و از سویی دیگر می‌تواند وقایع فاجعه‌بار را کاهش دهد. لذا در این پژوهش به بررسی قابلیت گاز زدایی در معادن کلاریز شرقی، رزمجای غربی، برناکی، بزرگ، رضی و تخت از مجموعه معادن زغال‌سنگ البرز شرقی با استفاده از روش سیستم‌های مهندسی سنگ با استفاده از مشخصات ذاتی و زمین‌شناسی پرداخته شده است. در این راستا تعداد ۹ پارامتر اصلی برای بررسی قابلیت گاز زدایی لحاظ شد و اندرکنش بین این پارامترها با استفاده از روش ارائه شده محاسبه شد. بر اساس روش سیستم‌های مهندسی سنگ پارامتر عمق (ضخامت) روباره پارامتر غالب و پارامتر میزان گازخیزی به عنوان پارامتر مغلوب شناسایی شد. روش ارائه شده یک روش ساده و کارآمد در ارزیابی پارامترهای مؤثر در گاز زدایی متان از معادن زغال‌سنگ است. نتایج به دست آمده نشان داد که معدن زغال‌سنگ رضی دارای قابلیت مناسبی برای اجرای عملیات گاز زدایی است.

کلمات کلیدی: گاز زدایی متان، سیستم‌های مهندسی سنگ، معادن زغال‌سنگ البرز شرقی.