GOSPODARKA SUROWCAMI MINERALNYMI

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Environmental impact assessment of mining activities. A new approach for mining methods selection

Introduction

One of the main tasks in exploitation of mineral deposits is to select a method suitable for the deposits specific features. Characteristics that have a major impact on the determination of the mining method includes: physical and geologic characteristics of the deposit, ground condition of the hanging wall, footwall, and ore zone, mining and capital cost and rate, availability and cost of labor, environmental consideration.

The selection of a mining method is shifting from an activity that is primary an art to one that is primarily science (Hartman, Mutmansky 2002). It should be noted that there is no single appropriate mining method for a deposit; there are usually two or more feasible method. Each method entails some inherent problems. Consequently, the optimum method is that method with the least problems. The factors that determine the mining method selection for exploitation of the deposit are grouped in six categories (Hartman, Mutmansky 2002):

— Spatial characteristics of the deposit.
— Geologic and hydrology conditions.
— Geotechnical properties.
— Economical consideration.

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— Technological factors.
— Environmental concerns.

Sometimes several mining methods may appear to be equally feasible. In order to further determine which method(s) is the most suitable, the input variables of mining cost, labor availability and environmental regulation should be considered in more detail (Nicholas 1993).

In mining method selection, it is important to remember that no one method is able to meet all of the requirements and conditions. Rather, the appropriate mining method is method that is technically feasible for the ore geometry and ground conditions, while also being a low operation cost and environmental impacts. This means that the best mining method is the one with the least technical and environmental problems. The mining engineer must balance all of the input parameters (such as environmental criteria) and select that method that appears to be the most suitable. Potential environmental hazards in mining activities can and should be accounted for in the mining method selection during feasibility or prefeasibility study of projects. However, this does not guarantee that all potential hazards can be avoided. It is therefore necessary to minimize environmental effects and hazards. This allows mining designers to minimize any future adverse environmental effects before the starting any activities.

Mining units should design in such a way that have the least impact on individuals and environment, because mining activities are in direct relationship with surrounding environment. Prevention or even lessening of the destructive effects in the start up, exploitation, and at the end of mining projects is the main goal of the environmental assessment (Mirmohammadi et al. 2007).

Depending on the technology in use and the mining methods adopted, mining activities can cause considerable environmental degradation and industrial pollution. Exploration and mine development may result in loss of vegetative cover, land degradation, and ecosystem disruption. Mining dumps and tailings are frequently the principal source of solid waste as well as liquid waste pollution. Mining may also cause the contamination of ground and surface waters with toxic chemicals and metals. Hence, mining method should select in such a way that have the least impact on environment, because mining operations are in direct relationship with ecosystem. Moreover mining industry is attracting increasing attention in many countries of the world, although it has a major impact on the environment. These effects should be identified at the initial mining method selection stage during a feasibility study. They should form part of the auditing of the project and the decision making regarding the project viability.

The paper focuses on environmental consideration in mining method selection. In facts, the main aim of this study is to present a model to determine environmental impacts of different mining methods in order to select the method which has minimum impact on environment.

Several specialists have studied on mining method selection problem until now and several methods have been developed in the past to evaluate suitable mining methods for an ore deposit based on its physical characteristics. These approaches consider the spatial characteristics of the deposit, geologic and hydrology conditions, geotechnical properties and so on. These approaches can be classified in three categories: profile/checklist, numerical ranking (scoring) and models based on multiple decision making theory (Samimi Namin et al. 2008). In profile/checklist and numerical ranking (scoring) methods, the influences of environmental effects on selection procedure are ignored. The most of the decision making model presented in order to determine optimal mining method eliminate the environmental parameters as effective criteria in their procedure but it is not discussed how determining of environmental impacts indicators. Application of proposed model with various mining method selection model eliminated the above mentioned disadvantage.

In order to introduce the suggested model, firstly, the environmental impacts of mining activities are presented. Then, the basic concepts of the model are introduced. Moreover, the proposed model is introduced based on the impacting factor and environmental components by modifying of Folchi algorithm. An application of the proposed model is carried out through a case study.

1. Field of the study

According Figure 1, mining activities include prospecting and exploration, development, mining operations, ore handling and transport, and mineral processing. The major aim of this study is minimize environmental impacts of mining operations by selecting of mining

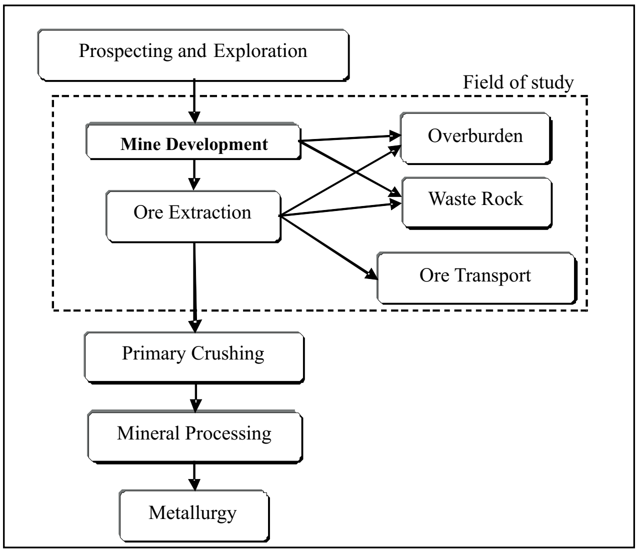

Fig. 1. Mining project activities and field of the study

Rys. 1. Działalność górnicza i zakres prac

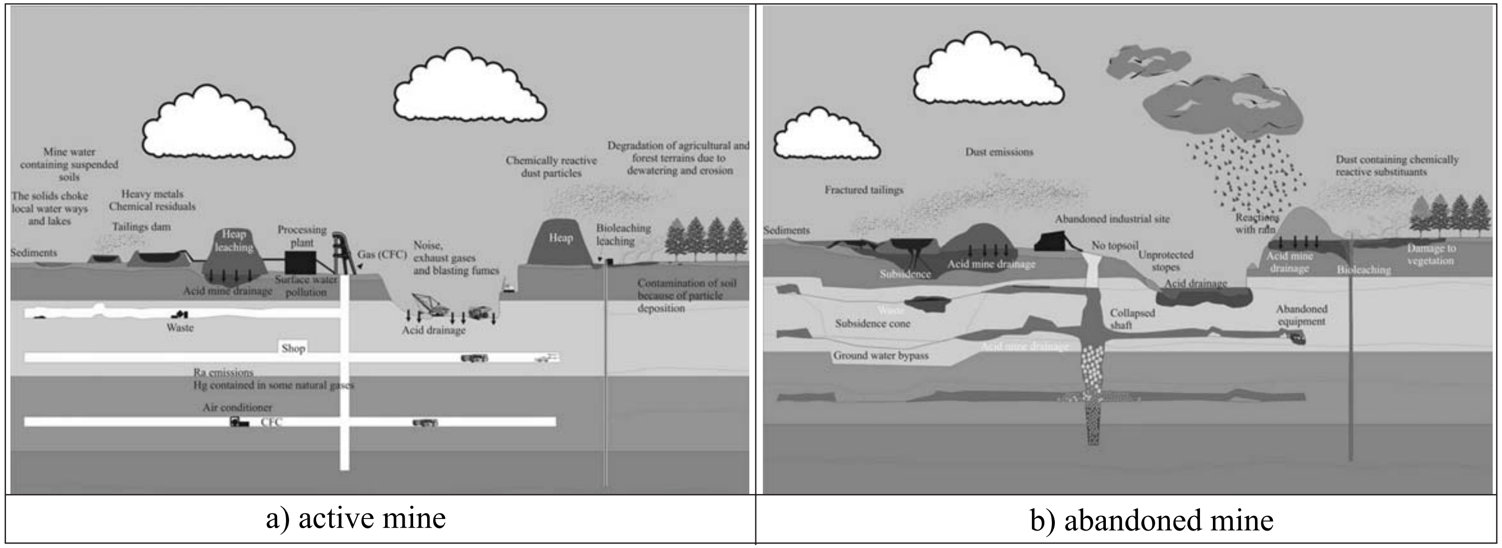

Fig. 2. General environmental impacts of mining activities (Haupt et al. 2001)

Rys. 2. Główne wpływy działalności górniczej na środowisko method where has a less effects on ecosystem. Therefore, this paper focuses on influence of different mining methods on the environment. Hence, the environmental impacts of some operations such as exploration and mineral pr0specting are ignored. Furthermore, the study will also look at ore handling and transport because have many differences for mining methods. A flow chart of the mining project activities and investigation field has been included in Figure 1.

On the other hand, the environmental impacts of mining projects can be divided into two group: the potential environmental impact during mine production and the environmental impact after mine closure. The illustrations in Figure 2-a and 2-b provide simple examples of some of the environmental hazards which occur at active and abandoned mines respectively. This study will indicate most of the potential environmental hazards arising from mining activity at both active and abandoned mines.

For an active mine, three primary activities have been identified which can generate potential environmental hazards; extraction, dewatering, and waste rock handling and storage. The hazards generated by active or abandoned mine site have been categorized as being either physical or chemical in nature. The environmental impacts identified at abandoned underground mine is uncontrolled ground movements as a major hazard in abandoned underground mines (Figure 2-b). Most of the hazards identified in abandoned mine sites, both open pit and underground, were the same as those identified at active sites. The only major difference was in the severity and areal extent of the impact.

2. Environmental impacts of mining methods issues

It is important at this stage to know the environmental impacts of mining activities and related literature. Environmental impacts of mining operations are numerous and diverse. At first, we will provide the reader with a brief description of the most common environmental impacts associated with mining methods and will present the summarized literature review. Various studies have been conducted so far on the devastating effects of mining on the environment and the ways to assess them. Some of those researcher are: White (1991), Pain et al. (1998), Tadesse (2000), Gobling (2001), Haupt et al. (2001), Blodgett, Kuipers (2002), Folchi (2003), Bascetin (2007), Monjezi et al. (2008).

The effects of open pit mining on the environment include land degradation, noise, dust, poisonous gases and pollution of water and so on (Dudka, Adriano 1997). Open-pit mining changes the topography and vegetation, as well. From the noise and vibration point of view, drilling and blasting operations as well as application of heavy vehicles are very important (Ashtiani 2005). Blasting, haulage and transportation are the main reasons for the dust generation. However, it may be produced in nearly all the phases of the processing plant, from the beginning point (crusher) to the end (drying of ore concentration) (Shu et al. 2001; Rawat 2003). Water pollution is another aspect of mine operations greatly impacting the environment (Fernandez-Galvez et al. 2007; Jordanov et al. 2007; Casiot et al. 2007;

Shikazono et al. 2008; Chalupnik, Wysocka 2008). If a springhead is situated in the mine area, the pollution endangers springs existed in the area (Blodgett, Kuipers 2002). Similarly, the contaminated water in the mining operation has vital impacts on the rivers, agriculture, fresh drinking waters and ecosystems, because of abundance of heavy metals, suspended solid particles and decreasing level of pH. Decreasing water level in the mines due to drainage not only causes undesirable changes in the nearby lakes but it can also threat the aquatics (Baker, Amacher 1982; Ritcy 1989). The main reason of environment pollution of the fresh water is the acidic water draining from mines (Shu et al. 2001). Mining operations with degradation of the land largely contribute to the corrosion of soil-a phenomenon that can be seen more in the surface mining activities (Sengupta 1993).

Much of the mine wastes has high concentration of heavy metals and toxic materials which are harmful for the environment. Various approaches have been offered by researchers such as Osanloo and Ataei (2003), Shahriar and Samimi Namin (2007) to waste dump site selection. Uncontrolled ground movements in the form of landslides are a major concern when the ore body extract by open pit methods. The greatest environmental hazard resulting from the underground mining methods is subsidence. Uncontrolled ground movement can occur during regular mining activity or years after mining has ceased. Using backfill decries waste has to be disposed on surface and subsidence are minimized. Smithen (1999) examines the need for considering environmental liabilities before describing the approach adopted in undertaking due diligence studies for the preparation of bankable feasibility documents and some of the difficulties experienced. Kocagil and Eduardo (1996) studied the effects of new environmental standards on mining industry and offered simple methodology to analyze the impacts of their proposed environmental standards on the mining industry.

Environment impacts of surface mining stabilize much faster than the underground and the nature healing process also being early. But environmental impact of surface mining remains visible to the public view and thus raises much of the outcry. Also, clearly the extra handling of overburden adds to the damage which is not possible in underground mining. But in underground mines, the effects are not immediately discernible. Since mining activity is started predominantly in forests, mountainous region or agricultural lands; its impact on local agrarian economy, prime natural resources, land flora and fauna and ground water are considered to be paramount. Environmental impacts of mining, by nature and significance, are dynamic in nature and always "more than what meets the eye". So when the visible macro impacts are observable, the micro impacts are too many to be kept count of, as are the intricacies of the nature (Bhattacharya 2003).

3. Environmental impact assessment of mining methods

The suggested algorithm is an attempt to modify the Folchi matrix method for assessment of the environmental effects of mining (include open pit and different underground methods) for optimal mining method selection. The Folchi method (2003) was first applied for a mining project in the Italian city of Sardina. It is the numerical expression of environmental impact of open pit mines. Later Folchi method applied for different open pit mines in Iran by Monjezi et al. (2008). Furthermore this algorithm has been developed by Mirmohammadi et al. (2007) for underground mining, in general form and without assumption for the type of methods in details. Folchi algorithm consists of the seven stages include; (1) Characterizing the pre-existing environmental context in terms of geology, geo-technics, hydrology, weather, economy and so on, (2) Identifying the impacting factors, which could modify the pre-existing environmental conditions in the mine life, (3) Defining the possible ranges for the magnitude of the variation caused by each impacting factor, (4) Singling out the environmental components whose pre-existing condition could be modified as a result of mining, (5) Correlating each impacting factor and each environmental component, (6) Estimating the specific magnitude for each impacting factor, using the already defined ranges, (7) Calculating the weighted sum of the environmental impact on each environmental component (Folchi 2003). Environmental assessments are performed by using matrix methods in which one dimension of the matrix is impacting factor and the other one is the environmental components which are affected by environmental factors. In this method, some parameters such as general health and safety, social relationships, weather and climate conditions, vegetation and, animals are defined first, for an area affected by a mining operation. Then, consequences of effective (directly or indirectly) mining indexes on the each of the environmental parameters are determined, by applying a rating system for each parameter, based on various concerned scenarios. The sum of all the ratings of effective parameters determines overall effect on each of the environmental indexes) Monjezi et al. 2008).

We consider ten major mining methods as scoring mining method selection model and identify environmental impacts considered to be relevant to these methods. The considered methods according to increasing operating costs are: open pit mining, block caving, sublevel stoping, sublevel caving, longwall, room and pillar, shrinkage, cut and fill, top slicing and square-set. In this paper each of described mining methods has environmental advantages and disadvantages. At first, it is necessary to introduce effective parameters for environmental assessment. To evaluate the effects of above mentioned mining methods, twelve parameters are proposed as impact factor which their magnitude of different mining methods are listed in Table 1.

In the first step, the weights of each impact factor must be determined in order to obtain the topics mentioned above by expert group. For severely destructive parameters, the impact factors mark is between 0 and 10, where 0 indicates ineffective impact factor, and 10 indicates the most critical effects for impact factor. Table 1 shows values of environmental impacting factors for ten mining methods.

In the next step, the environment sections which are affected with mining pollutions are defined as environmental components. The environment surrounding the mine was broken down into the ten components include: (1) Human health and safety, (2) Social relationship, (3) Water quality, (4) Air quality, (5) Ecosystem (Flora-Fauna), (6) Surface construction,

TABLE 1

Weighting of environmental impacting factor for the mining methods (matrix I_F)

TABELA 1

Wagi wpływu na środowisko różnych metod eksploatacji górniczej (macierz I_F)

Impacting factors	Open-pit	Block caving	Sublevel stoping	Sublevel caving	Long-wall	Room & pillar	Shrinkage stoping	Cut & fill	Top slicing	Square-set
1) Land use	10	4	3	4	4	3	2	1	2	2
2) Subsidence	1	10	5	9	10	7	8	1	10	8
3) Increase in traffic of the area	10	3	3	3	3	3	2	4	2	2
4) Interference with the surface water system	10	2	2	2	2	2	2	2	2	2
5) Interference with the underground water system	4	10	7	10	10	7	7	2	10	10
6) Dust and toxic gas emission	8	5	5	5	6	6	2	4	2	2
7) Noise pollution	8	6	4	6	6	6	4	6	2	2
8) Ground vibration	9	6	8	8	3	6	5	5	6	5
9) Fly-rock	10	2	2	2	0	2	2	2	2	1
10) Light (unfavorable condition)	2	10	10	10	10	10	10	10	10	10
11) Energy use	6	8	10	9	10	7	6	10	6	6
12) Employment of local work force	10	5	5	5	3	4	8	7	7	1

(7) Underground construction, (8) Area landscape, (9) Quietness and (10) Economical issues. The scoring is defined on the basis of the influence of impact factors on environmental components. Effect of each factor is expressed by four statements, Nil, Minimum (Min), Medium (Med), and Maximum (Max), on each environmental components. Table 2 shows the perturbation level of the impact factors for each environmental components and the related numeric weighting factors calculated as described above. Each factor changes the condition of each environmental component before mining, in respect of a coefficient. Assuming the sum of these coefficients equals to 10, and the Max effect is twice the Med, and the effect of Med is twice the Min, these coefficients lead to establish a matrix E_C ($[E_C]_{12\times10}$). Note that the effect of Nil is 0. In matrix E_C, sum of the columns equals to 10, because the sum of all the perturbation levels for each environmental component was normalized by imposing the sum equal to 10. Then, influence of impact factors on each environmental component could be written as Eq. 1.

$$[E_{CT}]_{1\times10} = [I_F]_{1\times12} \times [E_C]_{12\times10} \tag{1}$$

In the equations above, E_C is a 12×10 matrix with elements that represent the environmental components; also, I_F is a 1×10 matrix with elements which represent the values of impact factors. Finally, the overall components of matrix E_{CT} are depicted in a column graph which describes the amount of effect on each environmental component separately. For each mining methods, the overall effect on each environmental component is calculated by summing the weighted magnitudes of all the impact factors. For each mining methods, the overall effect on each environmental component is calculated by summing the weighted magnitudes of the all impact factors (see appendix). Furthermore, It was then possible to summarize the overall effect on each environmental component for the mining methods as a simple graphical representation as shown in Figure 3.

The Figure 3 shows the percentage values of environmental components for different mining methods. For example, it can be clearly seen that three environmental components (noise pollution or quietness, area landscape and social relationship) have a more effect on open pit mining in compare to other components. The block caving most effected on the underground and surface constructions and water quality components. Note that we do not compare the percentage of each method to other methods; we only show the compare between the environmental components for special mining method. On the other hand, the Figure 4 summarizes the overall effect of each mining methods on the environment.

In this graph of relative overall effects of mining methods on environmental parameters, we can see that the open pit mining is has the most environmental hazardous between other methods. Figure 4 shows that mining methods which use backfill (such as cut and fill stoping) are environmentally friendlier than others, as less waste has to be disposed of on surface and uncontrolled ground movements such as subsidence are minimized. Moreover, we can use this graph for mining method selection as well as following illustrative example.

TABLE 2

Weighted influence of each impacting factor on each environmental component (matrix E_C)

TABELA 2

Przeliczony wpływ każdego ze wskaźników wpływu na każdy składnik otoczenia (macierz E_C)

Impacting Factors	Environmental Components									
	human health & safety	social relationship	water quality	air quality	ecosystem (Flora--Fauna)	surface construction	underground construction	area landscape	quietness	economical issues
1	2	3	4	5	6	7	8	9	10	11
Land use	Min	Med	Med	Nil	Med	Nil	Nil	Max	Min	Max
	0.30	1	1.43	0	0.83	0	0	2.86	1.43	1.90
Subsidence	Nil	Med	Med	Nil	Med	Max	Max	Med	Nil	Max
	0	1	1.43	0	0.83	5	6.67	1.43	0	1.90
Increase in traffic of the area	Max	Max	Nil	Min	Min	Nil	Nil	Min	Med	Min
	1.17	2	0	0.91	0.42	0	0	0.71	2.86	0.48
Interference with the surface water system	Max	Nil	Max	Min	Max	Min	Nil	Max	Nil	Min
	1.17	0	2.86	0.91	1.67	1.25	0	2.86	0	0.48
Interference with the underground water system	Min	Nil	Max	Min	Max	Nil	Min	Nil	Nil	Min
	0.30	0	2.86	0.91	1.67	0	1.67	0	0	0.48
Dust and toxic gas emission	Max	Min	Min	Max	Max	Min	Nil	Min	Nil	Nil
	1.17	0.5	0.71	3.64	1.67	1.25	0	0.71	0	0
Noise pollution	Med	Max	Nil	Nil	Min	Nil	Nil	Nil	Max	Nil
	0.60	2	0	0	0.42	0	0	0	5.71	0

TABLE 2. cont.

TABELA 2. cd.

1	2	3	4	5	6	7	8	9	10	11
Ground vibration	Max	Med	Nil	Nil	Nil	Nil	Min	Nil	Nil	Nil
	1.17	1	0	0	0	0	1.67	0	0	0
Fly-rock	Max	Nil	Nil	Nil	Med	Nil	Nil	Nil	Nil	Nil
	1.17	0	0	0	0.83	0	0	0	0	0
Light	Max	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Med
	1.17	0	0	0	0	0	0	0	0	0.95
Energy use	Med	Min	Min	Max	Max	Med	Nil	Med	Nil	Max
	0.60	0.5	0.71	3.64	1.67	2.50	0	1.43	0	1.90
Employment of local work force	Nil	Max	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Max
	0	2	0	0	0	0	0	0	0	1.90
Total	10	10	10	10	10	10	10	10	10	10

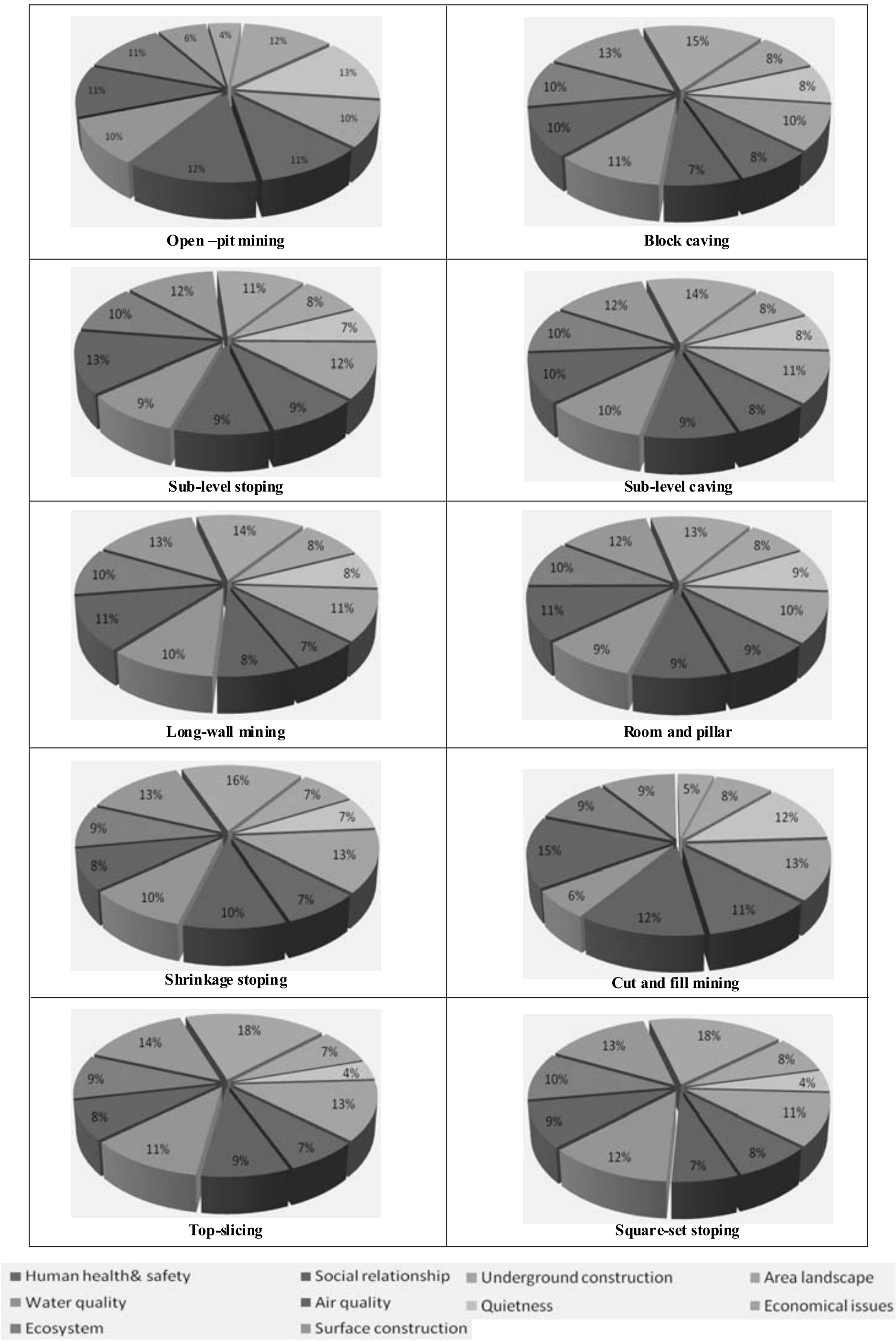

Fig. 3. The compare of each environmental component for each mining methods

Rys. 3. Porównanie każdego elementu środowiska dla każdej z metod górniczych

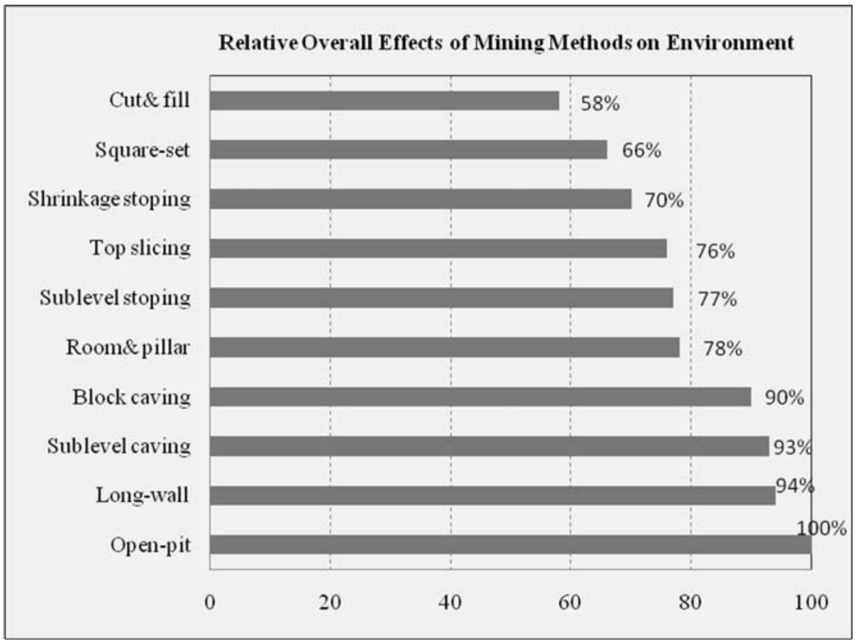

Fig. 4. The overall effects of each environmental component for each mining method

Rys. 4. Wpływ na środowisko każdej z metod górniczych

4. Illustrative example of application

In order to investigate the application of the proposed model, Gol-E-Gohar (GEG) deposit No.3, south of Iran, was chosen. GEG iron ore district is located at 55 km southwest of Sirjan in Kerman province. In fact, this district located at the center of a triangle consisting of Kerman, Shiraz and Bandar-Abbas with height of 1750 m from sea level (Figure 5). This area is a combination of metamorphic (Paleozoic) and sedimentary (Mesozoic) rocks, consisting mostly of gneiss, mica schist, amphibolites, quartz schist and calcite types of rocks. The GEG iron ore district includes six anomalies which anomaly No.1 was being extracted for many years with open pit mining. Recently, exploitation of the deposit No.3 has been considered. The above mentioned case example portrays a typical iron ore deposit located in the Iranian shield. In 1969 the Iran Barite Company began exploration at the site; exploration was delegated to the National Iron and Steel Company (NISCO), a government corporation. NISCO entered a joint venture with Granges International Mining of Sweden (GIM). NISCO and GIM advanced the exploration work programs and advanced the engineering and planning development of the GEG. A joint venture was undertaken with Aero Service Corporation in 1970, and an aerial magnetic survey was completed covering

Fig. 5. Location of GEG iron ore district in Iran

Rys. 5. Lokalizacja złoża rud żelaza GEG w Iranie

45 000 km^2 from Abadeh to Jasmurian (north of Bandar-Abbas). The survey identified many anomalous areas with high potential magnetic iron ores. The largest such anomaly, and the most prominent group of anomalies, situated at GEG. The Geoinstitute of Belgrade completed ground magnetic and gravimetric surveying over 74 km^2 at GEG in 1974. Subsequent drilling started on testing the six separate targets in 1975, intercepting good quality iron ore in all six. Geophysical modeling indicated the potential for 1135 Mt (exploration estimate only) for all six anomalies. Deposit No. 3 comprises two anomalous zones that join at depth. The southern area has a greater thickness of overburden (over 140 m) than the northern area (over 90 m). The southern area appears anomalous due to greater magnetic intensity reflected in the aeromagnetic data. Prior to 1993, 14 holes (3200 m) were drilled. In 1997 semi-detailed exploration commenced on deposit No.3 and finished in 1999. During this period GEG drilled 75 exploration holes for a total of 28 000 m (75 core drilling holes). The detailed exploration infill drilling commenced in 2001 and 50 holes have since been drilled. The total exploration holes in deposit No. 3 is 148 holes (approximately 46 000 m). The general shape of deposit No.3 GEG is generally semi-lenticular. The maximum vertical thickness of the ore-body ranges from 15–130 m and is 40 m thick in the central ore-body. The surrounding rocks consist of a metamorphic assemblage of probable Ordovician-Silurian age termed, the GEG complex litho stratigraphy unit. This assemblage at GEG includes quartzo-feldspathic gneisses, quartz chlorite, quartz muscovite and chlorite schist, and amphibolites. The overlying rock consists of muscovite chlorite schist and gneiss.

Acres Davy Consultants (ADC) has calculated 643 Mt Ore Reserves for deposit No.3 in 2004 (Samimi Namin et al. 2007).

Deposit No. 3 with length of 2200 m in north-south line and with average width of 1800 m in west of anomaly No. 1 which is located under a relatively flat field. The geometric and some the some geo-mechanical specifications of deposit No. 3 for mining method selection procedure are given in Table 3 based on the latest detailed exploration results (Samimi Namin 2008). In order to select the most suitable mining method according to technical characteristics of this deposit, ten methods are considered for comparison and competition.

Technical consideration: Several scoring methods have been developed in the past to evaluate suitable mining methods for an ore deposit based on physical characteristics of the deposit. The Nicholas method is one such procedure, which applies a numerical approach to rate different mining methods based on the ranking of specific input parameters.

TABLE 3

Specifications of GEG iron ore deposit No.3 (Samimi Namin 2008)

TABELA 3

Specyfikacje złoża rud żelaza GEG numer 3 (Samimi Namin 2008)

Criteria		Description
Ore zone	general shape	tabular
	ore thickness	15–130, average 40 meters
	ore dip	20 degree
	grade distribution	gradational
	depth	95 ~ 600 meters
	RQD	75%
	RSS	8.9
	RMR	good (60–80)
	ore reserve	643 million tons
	joint condition	filled (low strength)
Hanging wall	RQD	38%
	RSS	6
	RMR	good (60–80)
	joint condition	clean with a smooth surface
Foot wall	RQD	15%
	RSS	6.5
	RMR	good (60–80)
	joint condition	clean with a rough surface

A numeric rating for each mining method is arrived at by summing these rankings (Nicholas, Mark 1981; Nicholas 1993). The University of British Columbia (UBC) algorithm is a modification to the Nicholas approach (Miller et al. 1995). Using the UBC method the top four mining methods and their scores respectively are as following:

— Sublevel stoping: 34
— Open pit: 33
— Cut and fill stoping: 33
— Sublevel caving: 28

As you can see the scores the top of three methods is very near together and make a decision is not possible in this stage.

Economical consideration: At economical point in the selection process, it is important to be aware of the costs for each method. Accordingly, this section of the paper discusses mining method costs. Hartman and Mutmansky 2002, outlines the basic information on the typical commodities mined and relative costs. They provide a listing of relative mining costs that can be used for comparison purposes. The value100% of relative costs belongs to square-set stoping.

— Open pit: 5%
— Sublevel caving: 15%
— Sublevel stoping: 20%
— Cut and fill stoping: 55%

Environmental consideration: A complete analysis for the environmental impact of each mining method was carried out in previous section. The results are given in below:

— Cut and fill stoping: 58%
— Sublevel stoping: 77%
— Sublevel caving: 93%
— Open pit: 100%

Final decision making: For choosing a most suitable mining method from these four alternative (emphasis on the results of the technical, economical and environmental consideration), the Expert Choice (EC) software tool based on Analytic Hierarchy Process (AHP) can be used. AHP was used for mining and equipment selection by Bascetin 2004.

The first step is making judgments/pair-wise comparisons for objectives and alternatives. Normalized judgments/pair-wise comparisons data for deposit No. 3 GEG was entered to the software tool. After the all judgments have been completed and priorities have been calculated a synthesis is performed. Figure 6 shows the synthesis for each alternative after the data processed by EC software tool.

Sensitivity analyses from this selection will show the sensitivity of the alternatives with respect to the objectives below the goal. When performing a sensitivity analysis we may vary the priorities of the objectives and observe how the priorities of the alternatives would change. The graphic sensitivity analyses show how the alternatives priorities change when the objectives priorities increase or decrease. The performance sensitivity analysis shows

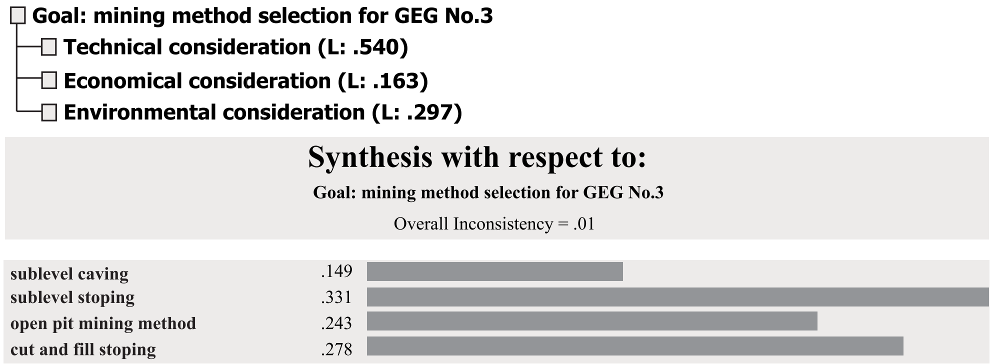

Fig. 6. The performance sensitivity analyses of the results

Rys. 6. Analiza wrażliwości dla uzyskanych wyników

how the alternatives were prioritized relative to other alternatives with respect to each objective as well as overall (Figure 7).

As you can see at the end of this decision, sublevel stoping with 0.33 points is the first and other methods which are lower rank than sublevel-stoping have lowered the chosen probability.

The above case study describes a mining method selection based on technical criteria with environmental impacts consideration and mitigation environmental impacts.

In mining method selection, the environmental impacts prediction of extraction operation is ones which should be considered, at the time of mining project feasibility study. As such, it is suggested when the feasibility study is being conducted, the environmental impacts must

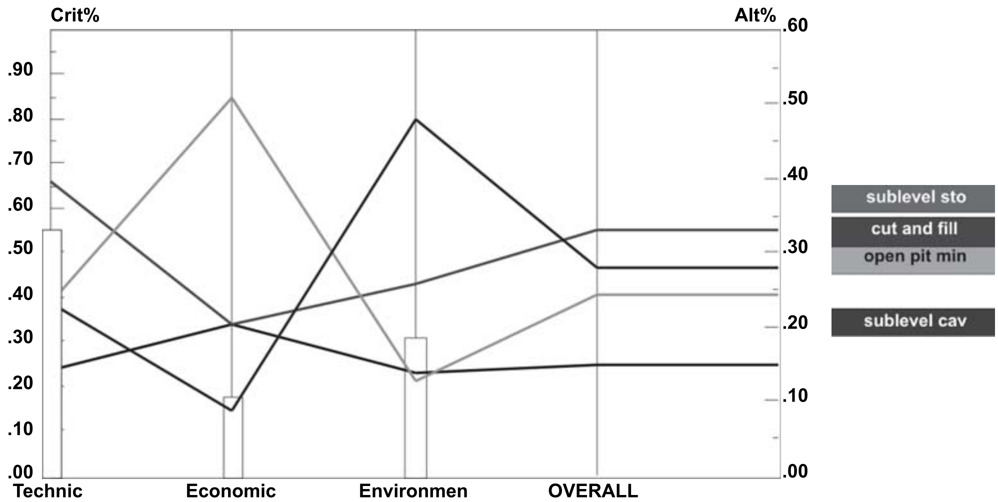

Fig. 7. The performance sensitivity analyses of the results

Rys. 7. Analiza wrażliwości dla uzyskanych wyników be predicted. Environmental impacts and related consideration must be taken into account in the mining method selection.

Conclusion

This paper discusses the concepts of environmental impacts associated with mining methods. Furthermore, it outlines the different mining methods based on related environmental impacts and illustrates application of results for mining method selection in order to mitigation mining environmental impacts. This paper presents a new approach related to the environmental impact assessment and selection of mining methods, supported by Folchi algorithm. As a means of assessing the mining engineering, the described approach is considered an appropriate starting point, and useful guideline for mining method selection. All mining methods involve an element of environmental impacts. There are certain generic, hazardous and impacts that are inherent to a particular mining method.

In this paper, environmental impacts of major mining methods very clearly assign responsibility for mining method selection procedure. The environmental performance assessments of inherent mining methods we have developed are especially adapted for the mining industry. It is the authors' belief that especially assessment systems for the mining sectors are necessary, and it is our hope that the new approaches presented in this paper stimulate further research on this area.

Appendix

For each mining methods, the overall effect on each environmental component is calculated by summing the weighted magnitudes of the all impact factors. The overall effects are sown in Tables 4–13.

TABLE 4

Final scores of each environmental component for open pit mining

TABELA 4

Końcowe wyniki dla każdego elementu środowiskowego dla kopalni odkrywkowej

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	3	10	14.3	0	8.3	0	0	28.6	14.3	19
Subsidence	0	1	1.43	0	0.83	5	6.67	1.43	0	1.9
Increase in traffic of the area	11.7	20	0	9.1	4.2	0	0	7.1	28.6	4.8
Interference with the surface water	11.7	0	28.6	9.1	16.7	12.5	0	28.6	0	4.8
Interference with the underground water	1.2	0	11.44	3.64	6.68	0	6.68	0	0	1.92
Dust and toxic gas emission	9.36	4	5.68	29.12	13.36	10	0	5.68	0	0
Noise pollution	4.8	16	0	0	3.36	0	0	0	45.68	0
Ground vibration	10.53	9	0	0	0	0	15.03	0	0	0
Fly-rock	11.7	0	0	0	8.3	0	0	0	0	0
Light	5.85	0	0	0	0	0	0	0	0	4.75
Energy use	3.6	3	4.26	21.84	10.02	15	0	8.58	0	11.4
Employment of local work force	0	20	0	0	0	0	0	0	0	19
Total	73.4	83.0	65.7	72.8	71.8	42.5	28.4	80.0	88.6	67.6

TABLE 5

Final scores of each environmental component for block caving

TABELA 5

Końcowe wyniki dla każdego elementu środowiskowego w systemie blokowym na zawał

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	1.20	4.00	5.72	0.00	3.32	0.00	0.00	11.44	5.72	7.60
Subsidence	0.00	10.00	14.30	0.00	8.30	50.00	66.70	14.30	0.00	19.00
Increase in traffic of the area	3.51	6.00	0.00	2.73	1.26	0.00	0.00	2.13	8.58	1.44
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	3.00	0.00	28.60	9.10	16.70	0.00	16.70	0.00	0.00	4.80
Dust and toxic gas emission	5.85	2.50	3.55	18.20	8.35	6.25	0.00	3.55	0.00	0.00
Noise pollution	3.60	12.00	0.00	0.00	2.52	0.00	0.00	0.00	34.26	0.00
Ground vibration	7.02	6.00	0.00	0.00	0.00	0.00	10.02	0.00	0.00	0.00
Fly-rock	2.34	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	4.80	4.00	5.68	29.12	13.36	20.00	0.00	11.44	0.00	15.20
Employment of local work force	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	45.4	44.5	63.6	61.0	58.8	78.8	93.4	48.6	48.6	58.5

TABLE 6

Final scores of each environmental component for sub-level stoping

TABELA 6

Końcowe wyniki dla każdego elementu środowiskowego w wybieraniu podpoziomowym

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	0.90	3.00	4.29	0.00	2.49	0.00	0.00	8.58	4.29	5.70
Subsidence	0.00	5.00	7.15	0.00	4.15	25.00	33.35	7.15	0.00	9.50
Increase in traffic of the area	3.51	6.00	0.00	2.73	1.26	0.00	0.00	2.13	8.58	1.44
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	2.10	0.00	20.02	6.37	11.69	0.00	11.69	0.00	0.00	3.36
Dust and toxic gas emission	5.85	2.50	3.55	18.20	8.35	6.25	0.00	3.55	0.00	0.00
Noise pollution	2.40	8.00	0.00	0.00	1.68	0.00	0.00	0.00	22.84	0.00
Ground vibration	9.36	8.00	0.00	0.00	0.00	0.00	13.36	0.00	0.00	0.00
Fly-rock	2.34	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	6.00	5.00	7.10	36.40	16.70	25.00	0.00	14.30	0.00	19.00
Employment of local work force	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Total	46.5	47.5	47.8	65.5	51.3	58.8	58.4	41.4	35.7	59.0

TABLE 7

Final scores of each environmental component for sub-level caving

TABELA 7

Końcowe wyniki dla każdego elementu środowiskowego w podbierkowym wybieraniu węgla

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	1.20	4.00	5.72	0.00	3.32	0.00	0.00	11.44	5.72	7.60
Subsidence	0.00	9.00	12.87	0.00	7.47	45.00	60.03	12.87	0.00	17.10
Increase in traffic of the area	3.51	6.00	0.00	2.73	1.26	0.00	0.00	2.13	8.58	1.44
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	3.00	0.00	28.60	9.10	16.70	0.00	16.70	0.00	0.00	4.80
Dust and toxic gas emission	5.85	2.50	3.55	18.20	8.35	6.25	0.00	3.55	0.00	0.00
Noise pollution	3.60	12.00	0.00	0.00	2.52	0.00	0.00	0.00	34.26	0.00
Ground vibration	9.36	8.00	0.00	0.00	0.00	0.00	13.36	0.00	0.00	0.00
Fly-rock	2.34	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	5.40	4.50	6.39	32.76	15.03	22.50	0.00	12.87	0.00	17.10
Employment of local work force	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Total	48.3	56.0	62.9	64.6	59.7	76.3	90.1	48.6	48.6	68.0

TABLE 8

Final scores of each environmental component for long-wall mining

TABELA 8

Końcowe wyniki dla każdego elementu środowiskowego w systemie ścianowym

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	1.20	4.00	5.72	0.00	3.32	0.00	0.00	11.44	5.72	7.60
Subsidence	0.00	10.00	14.30	0.00	8.30	50.00	66.70	14.30	0.00	19.00
Increase in traffic of the area	3.51	6.00	0.00	2.73	1.26	0.00	0.00	2.13	8.58	1.44
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	3.00	0.00	28.60	9.10	16.70	0.00	16.70	0.00	0.00	4.80
Dust and toxic gas emission	7.02	3.00	4.26	21.84	10.02	7.50	0.00	4.26	0.00	0.00
Noise pollution	3.60	12.00	0.00	0.00	2.52	0.00	0.00	0.00	34.26	0.00
Ground vibration	3.51	3.00	0.00	0.00	0.00	0.00	5.01	0.00	0.00	0.00
Fly-rock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	6.00	5.00	7.10	36.40	16.70	25.00	0.00	14.30	0.00	19.00
Employment of local work force	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.70
Total	41.9	49.0	65.7	71.9	62.2	85.0	88.4	52.2	48.6	68.0

TABLE 9

Final scores of each environmental component for room and pillar

TABELA 9

Końcowe wyniki dla każdego elementu środowiskowego w systemie filarowo-komorowym

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	0.90	3.00	4.29	0.00	2.49	0.00	0.00	8.58	4.29	5.70
Subsidence	0.00	7.00	10.01	0.00	5.81	35.00	46.69	10.01	0.00	13.30
Increase in traffic of the area	3.51	6.00	0.00	2.73	1.26	0.00	0.00	2.13	8.58	1.44
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	2.10	0.00	20.02	6.37	11.69	0.00	11.69	0.00	0.00	3.36
Dust and toxic gas emission	7.02	3.00	4.26	21.84	10.02	7.50	0.00	4.26	0.00	0.00
Noise pollution	3.60	12.00	0.00	0.00	2.52	0.00	0.00	0.00	34.26	0.00
Ground vibration	7.02	6.00	0.00	0.00	0.00	0.00	10.02	0.00	0.00	0.00
Fly-rock	2.34	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	4.20	3.50	4.97	25.48	11.69	17.50	0.00	10.01	0.00	13.30
Employment of local work force	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.60
Total	44.7	48.5	49.3	58.2	50.5	62.5	68.4	40.7	47.1	55.2

TABLE 10

Final scores of each environmental component for shrinkage

TABELA 10

Końcowe wyniki dla każdego składnika środowiskowego w wybieraniu magazynowym

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	0.60	2.00	2.86	0.00	1.66	0.00	0.00	5.72	2.86	3.80
Subsidence	0.00	8.00	11.44	0.00	6.64	40.00	53.36	11.44	0.00	15.20
Increase in traffic of the area	2.34	4.00	0.00	1.82	0.84	0.00	0.00	1.42	5.72	0.96
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	2.10	0.00	20.02	6.37	11.69	0.00	11.69	0.00	0.00	3.36
Dust and toxic gas emission	2.34	1.00	1.42	7.28	3.34	2.50	0.00	1.42	0.00	0.00
Noise pollution	2.40	8.00	0.00	0.00	1.68	0.00	0.00	0.00	22.84	0.00
Ground vibration	5.85	5.00	0.00	0.00	0.00	0.00	8.35	0.00	0.00	0.00
Fly-rock	2.34	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	3.60	3.00	4.26	21.84	10.02	15.00	0.00	8.58	0.00	11.40
Employment of local work force	0.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.20
Total	35.6	47.0	45.7	39.1	40.9	60.0	73.4	34.3	31.4	60.4

TABLE 11

Final scores of each environmental component for cut and fill

TABELA 11

Końcowe wyniki dla każdego składnika środowiskowego w systemie eksploatacji z podsadzką

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	0.30	1.00	1.43	0.00	0.83	0.00	0.00	2.86	1.43	1.90
Subsidence	0.00	1.00	1.43	0.00	0.83	5.00	6.67	1.43	0.00	1.90
Increase in traffic of the area	4.68	8.00	0.00	3.64	1.68	0.00	0.00	2.84	11.44	1.92
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	0.60	0.00	5.72	1.82	3.34	0.00	3.34	0.00	0.00	0.96
Dust and toxic gas emission	4.68	2.00	2.84	14.56	6.68	5.00	0.00	2.84	0.00	0.00
Noise pollution	3.60	12.00	0.00	0.00	2.52	0.00	0.00	0.00	34.26	0.00
Ground vibration	5.85	5.00	0.00	0.00	0.00	0.00	8.35	0.00	0.00	0.00
Fly-rock	2.34	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	6.00	5.00	7.10	36.40	16.70	25.00	0.00	14.30	0.00	19.00
Employment of local work force	0.00	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.30
Total	42.1	48.0	24.2	58.2	37.6	37.5	18.4	30.0	47.1	49.4

TABLE 12

Final scores of each environmental component for top-slicing

TABELA 12

Końcowe wyniki dla każdego składnika środowiskowego przy wybieraniu stropowo-schodowym

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	0.60	2.00	2.86	0.00	1.66	0.00	0.00	5.72	2.86	3.80
Subsidence	0.00	10.00	14.30	0.00	8.30	50.00	66.70	14.30	0.00	19.00
Increase in traffic of the area	2.34	4.00	0.00	1.82	0.84	0.00	0.00	1.42	5.72	0.96
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	3.00	0.00	28.60	9.10	16.70	0.00	16.70	0.00	0.00	4.80
Dust and toxic gas emission	2.34	1.00	1.42	7.28	3.34	2.50	0.00	1.42	0.00	0.00
Noise pollution	1.20	4.00	0.00	0.00	0.84	0.00	0.00	0.00	11.42	0.00
Ground vibration	7.02	6.00	0.00	0.00	0.00	0.00	10.02	0.00	0.00	0.00
Fly-rock	2.34	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	3.60	3.00	4.26	21.84	10.02	15.00	0.00	8.58	0.00	11.40
Employment of local work force	0.00	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.30
Total	36.5	44.0	57.2	41.9	46.7	70.0	93.4	37.2	20.0	63.7

TABLE 13

Final scores of each environmental component for square-set stoping

TABELA 13

Końcowe wyniki dla każdego składnika środowiskowego przy zastosowaniu obudowy kasztowej

Impacting Factors	Environmental Components									
	human health& safety	social relationship	water quality	air quality	ecosystem	surface construction	underground construction	area landscape	quietness	economical issues
Land use	0.60	2.00	2.86	0.00	1.66	0.00	0.00	5.72	2.86	3.80
Subsidence	0.00	8.00	11.44	0.00	6.64	40.00	53.36	11.44	0.00	15.20
Increase in traffic of the area	2.34	4.00	0.00	1.82	0.84	0.00	0.00	1.42	5.72	0.96
Interference with the surface water	2.34	0.00	5.72	1.82	3.34	2.50	0.00	5.72	0.00	0.96
Interference with the underground water	3.00	0.00	28.60	9.10	16.70	0.00	16.70	0.00	0.00	4.80
Dust and toxic gas emission	2.34	1.00	1.42	7.28	3.34	2.50	0.00	1.42	0.00	0.00
Noise pollution	1.20	4.00	0.00	0.00	0.84	0.00	0.00	0.00	11.42	0.00
Ground vibration	5.85	5.00	0.00	0.00	0.00	0.00	8.35	0.00	0.00	0.00
Fly-rock	1.17	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00
Light	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
Energy use	3.60	3.00	4.26	21.84	10.02	15.00	0.00	8.58	0.00	11.40
Employment of local work force	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90
Total	34.1	29.0	54.3	41.9	44.2	60.0	78.4	34.3	20.0	48.5

REFERENCES

Ashtiani M., 2005 – Environmental considerations in the mines. Paper presented at the 1st Environmental Considerations in the Mines, National Conference, Kerman, Iran, pp. 30–38.

Baker D.E., Amacher M.C., 1982 – Nickel, copper, zinc and cadmium. [In:] Page AL, Miller RH, Keeney DR (eds.) Methods of soil analysis: part 2. Chemical and microbiological properties, 2nd edn. Agronomy no. 9. American Society of Agronomy and Soil Science Society of America, Madison, pp. 323–336.

Bascetin A., 2004 – An application of the analytic hierarchy process in equipment selection at orhaneli open pit coal mine. Transactions of the Institutions of Mining and Metallurgy (AusIMM), Section A-Mining Technology 113, pp. 192–199.

Bascetin A., 2007 – A decision support system using analytical hierarchy process (AHP) for the optimal environmental reclamation of an open pit mine. Environmental Geology 52, pp. 663–672.

Bhattacharya J., 2003 – Principles of mine planning, Published by Sunil Sachdev and printed by Ravi Sachdev at Allied Publisher PVT. LTD. New Delhi, pp. 30–31.

Blodgett S., Kuipers J.R., 2002 – Technical report on underground hard-rock mining: subsidence and hydrologic environmental impacts. Center for Science in Public Participation, pp. 36–38.

Casiot C., Ujevic M., Munoz M., Seidel J.L., Elbaz-Poulichet F., 2007 – Antimony and arsenic mobility in a creek draining an antimony mine abandoned 85 years ago (upper Orb basin, France). Appl Geochem 22, pp. 788–798.

Chalupnik S., Wysocka M., 2008 – Radium removal from mine waters in underground treatment installations. J Environ Radioact (in press).

Dudka S., Adriano D.C., 1997 – Environmental impacts of metal ore mining and processing: a review. J Environ Qual 26, pp. 590–602.

Fernandez-Galvez J., Barahona E., Iriarte A., Mingorance M.D., 2007 – A simple methodology for the evaluation of groundwater pollution risks. Sci Total Environ 378, pp. 67–70.

Folchi R., 2003 – Environmental impact statement for mining with explosives: a quantitative method, I.S.E.E. Paper presented at the 29th Annual Conference on Explosives and Blasting Technique. Northville, Tennessee, USA.

Gobling S., 2001 – Entropy production as a measure for resource use applied to metallurgical processes. Paper presented at The Science and Culture of Industrial Ecology (ISIE Conference).

Hartman H.L., Mutmansky J.M., 2002 – Introductory mining engineering. Second edition, John Wiley & Sons.

Haupt C., Mistry M., Wilde J., 2001 – Development of measures to minimize adverse ecological effects generated by abandoned mines in developing countries. Institut fur Bergbaukunde I. der Rheinisch--Westfa¨lischen Technischen Hochschule Aachen 51–54.

Jordanov S.H., Maletic M., Dimitrov A., Slavkov D., Paunovic P., 2007 – Waste waters from copper ores mining/flotation in 'Bucbim' mine: characterization and remediation. Desalination 213, s. 65–71.

Miller L., Pakalnis R., Poulin R., 1995 – UBC Mining Method Selection. International Symposium on Mine Planning and Equipment Selection, Singh.

Mirmohammadi M., Gholamnejad J., Fattahpour V., Seyedsadri P., Ghorbani Y., 2007 – Designing of an environmental assessment algorithm for underground mining projects, SGEM, Bulgaria, Varna.

Monjezi M., Shahriar K., Dehghani H., Samimi Namin F., 2008 – Environmental impact assessment of open pit mining in Iran, Environmental Geology, Springer-verlag.

Nicholas D., Mark J., 1981 – Feasibility study-selection of a mining method integrating rock mechanics and mine planning. 5th Rapid Excavation and Tunneling Conference, San Francisco, Vol. 2, pp. 1018–1031.

Nicholas D., 1993 – Selection Procedure. Mining engineering handbook, Hartman H, SME, New York, pp. 2090–2105.

Osanloo M., Ataei M., 2003 – Factors affecting the selection of site for arrangement of pit rock dumps. Journal of Mining Science, 39, 148–153.

Pain D.J., Sanchez A., Meharg A.A., 1998 – The Donana ecological disaster: Contamination of a world heritage estuarine marsh ecosystem with acidified pyrite mine waste. Sci Total Environ 222, pp. 45–54.

Rawat N.S., 2003 – A study of physicochemical characteristics of respirable dust in an Indian coal mine. Sci Total Environ 23, pp. 47–54.

Ritcy G.M., 1989 – Tailings management: problems and solutions in the mining industry. Environ Int 26, pp. 389–394.

Samimi Namin F., (in press) Ph.D. – Thesis, Faculty of Mining and Metallurgical Engineering. Amirkabir University of Technology, Tehran, Iran.

Samimi Namin F., Shahriar K., Ataee pour M., Dehghani H., 2008 – A new model for mining method selection of mineral deposit based on fuzzy decision making. Southern African Institute of Mining and Metallurgy (SAIMM), 108, pp. 381–391.

Samimi Namin F., Shahriar K., Dehghani H., 2007 – Feasibility study and economic evaluation for deposit No 3 of Gol-e-Gohar iron ore deposit. Iron Ore Conference, Australia, Perth, pp. 20–22.

Sengupta M., 1993 – Environmental Impacts of Mining: Monitoring, Restoration, and Control, CRC Press. ISBN 0873714415, pp. 3–20.

Shahbazi A., Khorasani N., 2003 – Investigation about interaction of environmental and mine with matrix method (case study: Lashtor stone mine in Isfahan). The 5th Congress on Safety, Occupational and Environmental Health in Mines and Related Industries (In Persian).

Shahriar K., Samimi Namin F., 2007 – A new approach to waste dump site selection according to the fuzzy decision-making process. Canadian Institute of mining, metallurgy and petroleum CIM, vol. 100, pp. 1–6.

Shikazono N., Zakir H.M., Sudo Y., 2008 – Zinc contamination in river water and sediments at Taisyu Zn–Pb mine area, Tsushima Island, Japan. J Geochem Explor 98, pp. 80–88.

Shu W.S., Ye Z.H., Lan C.Y., Zhang Z.Q., Wong M.H., 2001 – Acidification of lead/zinc mine tailings and its effect on heavy metal mobility. Environ Int 26, pp. 389–394.

Smithen A.A., 1999 – Environmental considerations in the preparation of bankable feasibility documents. Southern African Institute of Mining and Metallurgy (SAIMM), October-December, pp. 317–319.

Tadesse S., 2000 – Environmental policy in mining: corporate strategy and planning for closure. A contribution to published book, ISBN 1–56670-365-4, pp. 415–422.

White L., 1991 – Environmental engineering-an evolving discipline of increasing importance to mining. Min Eng 43, p. 1309.

OCENA WPŁYWU GÓRNICTWA NA ŚRODOWISKO. NOWE PODEJŚCIE DO WYBORU METOD EKSPLOATACJI

Słowa kluczowe

Oocena wpływu na środowisko, przemysł górniczy, wybór metod ekspoatacji, zmodyfikowana metoda Folchiego, złoże rudy żelaza Gol-E-Gohar w Iranie

Streszczenie

Działania górnicze, począwszy od rozpoznania złóż aż po transport finalnego produktu, to szereg etapów prowadzących do zanieczyszczenia środowiska. Metody eksploatacji mogą i powinny być dobierane w taki sposób, by ich wpływ na środowisko i człowieka był jak najmniejszy. Różni specjaliści zajmujący się górnictwem przeprowadzili do tej pory szereg badań dotyczących zagadnienia wyboru metod eksploatacji. Niestety, dotychczas stosowane podejścia nie brały pod uwagę środowiska i metodologii, w których wpływ na środowisko stanowiłby kryterium oceny. Ta praca przedstawia wpływ operacji górniczych na środowisko w zależności od zastosowanych systemów eksploatacji. W tym celu wykorzystano metodę Folchi'ego, odpowiednio zmodyfikowaną dla potrzeb oceny wpływu na środowisko, do której włączono metody eksploatacji i opracowano procedury pomagające dokonać wyboru tych właściwych. Na wstępie przedstawione zostały ogólne i objaśniające informacje na temat wpływu górnictwa na zanieczyszczenie środowiska. Następnie zaprezentowano przedmiot i cele badania. Praca przedstawia ocenę środowiskową dla różnych systemów eksploatacji. Omawia również szczegółowo wpływ poszczególnych metod eksploatacji na środowisko wraz z oceną. W podsumowaniu zawarto uwagi końcowe oraz przedyskutowano ich zastosowania dla wyboru metod eksploatacji na przykładzie studium przypadku. Główną zaletą nowego algorytmu jest fakt, iż bierze pod uwagę interakcję wielu czynników środowiskowych przy ocenie wpływu na środowisko wybranych metod eksploatacji.

ENVIRONMENTAL IMPACT ASSESSMENT OF MINING ACTIVITIES. A NEW APPROACH FOR MINING METHODS SELECTION

Key words

Environmental impacts assessment, mining industry, mining method selection, modified folchi approach, Gol-E-Gohar iron ore deposit in Iran

Abstract

Mining activities from exploration to final material handling up to shipment pass through various stages where environmental pollution results. Mining method can and should be selected in such a way that their impact on individuals and environmental to be minimized. Until now, different mining specialists have carried out many studies on mining method selection. Unfortunately neither of previous approaches takes into account of the environmental consideration and methodology for assessment of environmental impacts criterion. This paper discusses environmental impacts of mining operations associated with different mining methods. For this purpose, the Folchi approach was modified for environmental impact assessment which associates the mining methods inherently and developed of a procedure to assist a selecting of mining method. Firstly, the general and explanatory information about effects of mining on the environmental pollution are given in the paper. Moreover field and purposes of the study are introduced. The paper presents an environmental assessment for different mining methods. And, secondly, the impacts of each mining methods on environment are focused and discussed. Finally, some concluding remarks are made and the related applications for the mining method selection are discussed by using in a case study. As the main advantage, this new algorithm takes several environmental issues and their interaction takes into consideration for environmental assessment of a mining method selection.