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Research Article

Environmental Impact Assessment (EIA) of a gold mine tailing through the multi-criteria decision making tool

Abstract

Gold mine tailings dams are a high risk part of mining as they contain hazardous materials such as cyanide, mercury and arsenic from processing operations which present a risk to the public and to the environment. When tailing dams fail, the impact is disastrous for humans and the natural environment. The International Commission on Large Dams (ICOLD) collected 221 case records of tailing facility failure incidents worldwide to determine the causes of these incidents. The main causes of these incidents and reported cases of failure were found to be lack of control during the construction, lack of control of the water balance and a general lack of understanding of the features that control safe operations. The important elements to improve the safety and stability of tailings disposal facilities are geotechnical investigation, engineered design, construction, operation and monitoring of the tailings storage facility. Quality engineering is essential in the construction of a fill dam because the materials used have lower strength properties than the concrete dams thus the performance and safety of tailing dam is very important. In this research, the application of Multi Criteria Decision Making (MCDM) methods has been investigated in the Environmental Impact Assessment (EIA) process. For this purpose, Zarshoran Gold mine in the north west of Iran has been selected as a case study. The ability of MCDM methods in EIA has been tested in two parts. In the first part, the best site for dumping tailingss in the case study area has been identified by using TOPSIS method. The weights and criteria are specified to rank the sites and one of the sites has been chosen as the best place in the study area. Results show that the TOPSIS is a powerful method in the EIA process for identifying significance environmental impact and sorting the alternatives.

Introduction

Tailings are residual materials of various procedures in metal extraction from different ores, or coal washing processes. Usually milling and hydrometallurgical processes result in a huge volume of residual slurry which may contain heavy metals and many other toxic materials at concentrations higher than environmental standards [1]. Moreover, mining wastes may comprise specific chemical additives, although the concentration levels are generally of no concern [2]. Tailings disposal is an important issue in saving the environment, especially in the case of low grade deposits where the volume of tailing materials is considerable. The size of solid particles of tailing depends on the ore nature and its dressing procedures. As a case in point, tailings in heavy media processes are relatively coarse, whereas those resulted from flotation processes are fine. Usually, in mineral processing plants, tailings are concentrated into high solid percent pulp using thickeners and piled afterwards still having considerable amount of water [3]. Apart from aesthetic imperfections which are caused by stockpiling of tailings, leakage of toxic materials such as reagents and heavy metals may pose serious threats against the environment [4].

EIA is a process aimed to identify, predict, evaluate, and balance the biophysical, social, and other impacts prior to making basic decisions [5]. In fact, it is a tool in environmental administration used to assess the effects of project activities on the environment with an avoidance approach [6]. Regarding the importance and necessity of having full recognition of the area and its environmental status, accurate perception of the impacts caused by project activities, and the need for presentation and classification of the impacts to better demonstrate the results to the decision makers, various techniques are proposed by the researchers [7]. These techniques includes: Ad-Hoc, check lists, matrices, GIS mapping, and media methods [8].

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Simple problems having few criteria and options for decision making may be solved with no need to specific methods; however, when the number of criteria and options increase, systematic methods are used to solve the problem and make the proper decisions [9]. Using these techniques help structuring the values and imaginations of decision makers.

One efficient tool in solving multi-objective/multi-criteria problems is multi-criteria decision analysis which is a model of decision making that reasonably optimizes the problem solving using multiple criteria (sometimes heterogeneous [10]. Multi-criteria decision analysis may be performed either by multi-objective decision making or multi-criteria decision making [11]. In multi-criteria decision making of problems, options are prioritized according to various criteria. A decision making problem can be organized in form of classic multi-criteria decision making techniques [12]. These techniques include AHP, SAW, TOPSIS, ANP, and KIKOR that started to develop in 1980s.

In the current study, an attempt was made to identify the best site for dumping tailing in the case study area using TOPSIS method. Additionally, the significant of environmental impact has been assessed using MCDM based on SAW techniques.

Materials and Methods

In the present study the SAW method was used to assess environmental impact assessment of mining activities in the study area, and TOPSIS method was applied to select the best location for the dumping site. Thus, the two mentioned method was described in this section. It should be noted that the questionnaire (n=15) was used to to obtain the necessary data and weight the criteria.

SAW method

The method has been first proposed by Hwang and Yoon in 1981 as a weighted linear combination method. In this method after de-scaling of the decision matrix, the weighted de-scaled decision matrix is obtained by applying weight coefficients of criteria; accordingly the score of each option is calculated [13]. In a multi-criteria decision making problem, if *n* criteria and *m* options are present, the decision matrix is as follows:

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \cdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}$$

Where x_{ij} is the operation of option *i* $(i = 1, 2, \ldots, m)$ in relation to criterion*j* $(j = 1, 2, \ldots, n)$.

In order to de-scale the decision matrix, *R* matrix is defined as

$$R = \begin{pmatrix} r_{11} & \ldots & r_{1n} \\ \ldots & \ldots & \vdots \\ r_{m1} & \ldots & r\cdots_{mn} \end{pmatrix}$$

Where the elements are calculated as

$$r_{ij} = \frac{x_{ij}}{\max\{x_{ij}\}}$$

$$r_{ij} = \frac{\frac{1}{x_{ij}}}{\max\{\frac{1}{x_{ij}}\}} = \frac{\min\{x_{ij}\}}{x_{ij}}$$

Regarding the significance coefficient of various criteria in decision making, criteria weight vector is defined as $\left[w_1, w_{2,\cdots,} w_n\right]$ and the best option is selected by

$$A^* = \{A_i / \max \sum_{j=1}^{m} w_j r_{ij}\}$$

TOPSISI Method

In the present study the TOPSIS method was used to select the best location for the dumping site. In this regards, a negative ideal solution maximizes the cost criteria or attributes and minimizes the benefit criteria or attributes, whereas a positive ideal solution maximizes the benefit criteria or attributes and minimizes the cost criteria or attributes. The TOPSIS method is explained in a succession of six steps as follows:

Step 1: Calculate the normalized decision matrix. The normalized value r_{ij} is calculated as follows:

$$r_{ij} = x_j \sqrt{\sum_{i-1}^{m} x_j^2} \quad \text{i =1, 2, ..., m and j = 1, 2, ..., n.}$$

Step 2: Calculate the weighted normalized decision matrix. The weighted normalized value v_j is calculated as follows:

$$v_{ij} = r_j \times w_j \quad \text{i =1, 2,..., m and j = 1, 2, ..., n.} \qquad (1)$$

where w_j is the weight of the j^{th} criterion or attribute and $\sum_{j=1}^{n} w_j = 1$.

Step 3: Determine the ideal (A^*) and negative ideal (A^-) solutions.

$$A^* = \{(\max_i v_j \mid j \in C_b)(\min_i v_j \mid j \in C_c)\} = \{v_j^* \mid j = 1,2,\ldots,m\} \qquad (2)$$

$$A^- = \{(\min_i v_j \mid j \in C_b)(\max_i v_j \mid j \in C_c)\} = \{v_j^- \mid j = 1,2,\ldots,m\} \qquad (3)$$

Step 4: Calculate the separation measures using the m-dimensional Euclidean distance. The separation measures of each alternative from the positive ideal solution and the negative ideal solution, respectively, are as follows:

$$S_i^* = \sqrt{\sum_{j=1}^{m} (v_j - v_j^*)^2}, j = 1,2,\ldots,m \qquad (4)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_j - v_j^-)^2}, j = 1,2,\ldots,m \qquad (5)$$

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Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative A_i with respect to A^* is defined as follows:

$$RC_i^* = \frac{S_i^-}{S_i^* + S_i^-}, i = 1,2,\ldots,m \qquad (6)$$

Step 6: Rank the preference order

Case study area

The processing plant of refractory gold ore in As-Sbsulfurcontaining deposits in Zarshoran Gold Mine, Takab, WestAzarbaijan was selected as the case study area.

Result and Discussion

To choose the best siting dump, 9 locations and 10 criteria were defined. The questionnaire was applied to provide quantitative data to compare the sites locations and criteria. The dumping site distance from the mine is the first criteria that should be weighted in the questionnaire. Moreover, the distance from the residential area and sensitive ecosystems are the second and third criteria. The vulnerability to flood and earthquake estimate the vulnerability of the selected sites (A1 to A9) to flood or earthquake based on the expert opinions and distance from the faults. The energy consumption was estimated through the access to water and electricity based on the expert opinions. The ease of access to the local employees is categorized ad supply of human resource that weighted based on the expert opinions. The results of the applied MCDM methods are more described as follows.

Prioritizing locational options in order to dumping tailings using TOPSIS technique

This stage consisted of the following steps:

(1). First, 9 options (A1-A9) were selected as suggested options for the unit establishment.

(2). Important technical and locational sections were determined surveying the state of the art, and a specific score was assigned to each [14].

(3). A specific score (within 0-10) was assigned to each selected point in each notified item (Table 1).

(4). Next, the input data should be de-scaled using the vector method (Table 2).

(5). The criterion weights were normalized by vector method as they are listed in table 3.

(6). The weighted normalized decision matrix may be constructed at this stage (Table 4).

(7). The maximum and minimum values in each column were determined (Table 5).

(8). Next, the ideal and non-ideal values in each column were determined (Table 6).

Table 1: Scoring to the locational options in each criterion.

decision matrix	distancefrom the mine	closenessto residential areas	impacton surrounding ecosystem	vulnerabilityto flood and earthquake	access towater and electricity	access tovehicles	unitsecurity	supplyof human resources	closenessto agricultural fields	propertopographical situations	accessroads
locational option / impact type	negative	negative	negative	negative	Positive	positive	positive	positive	negative	positive	positive
A_9	5	0	2	0	10	10	10	10	2	5	10
A_8	4	2	3	2	5	6	7	10	1	1	5
A_7	2	8	8	7	8	10	10	10	8	5	10
A_6	5	0	2	2	4	5	5	5	1	2	10
A_5	2	0	3	2	5	3	4	3	8	5	3
A_4	0	0	2	5	3	2	3	3	0	0	2
A_3	4	5	5	5	10	10	8	10	5	3	10
A_2	4	0	10	10	10	10	5	10	10	2	10
A_1	5	0	10	10	10	10	5	10	10	2	10

Table 2: The normalized data of locational options.

locational optioni	distance from the mine	closeness to residential areas	impact on surrounding ecosystem	vulnerability to flood and earthquake	access to water and electricity	access to vehicles	unit security	supply of human resources	closeness to agricultural fields	proper topographical situations	access roads
A_9	0.44	0	0.11	0	0.43	0.42	0.49	0.39	0.11	0.51	0.4
A_8	0.35	0.21	0.17	0.11	0.21	0.25	0.34	0.39	0.05	0.1	0.2
A_7	0.17	0.83	0.45	0.4	0.34	0.42	0.49	0.39	0.42	0.51	0.4
A_6	0.44	0	0.11	0.11	0.17	0.21	0.25	0.2	0.05	0.2	0.4
A_5	0.17	0	0.17	0.11	0.21	0.13	0.2	0.12	0.42	0.51	0.12
A_4	0	0	0.11	0.28	0.13	0.08	0.15	0.12	0	0	0.08
A_3	0.35	0.52	0.28	0.28	0.43	0.42	0.39	0.39	0.26	0.3	0.4
A_2	0.35	0	0.56	0.57	0.43	0.42	0.25	0.39	0.53	0.2	0.4
A_1	0.44	0	0.56	0.57	0.43	0.42	0.25	0.39	0.53	0.2	0.4

(9). A matrix is constructed for the distance from ideal and non-ideal values (Table 7).

(10). Then the similarity index was constructed for each option as it is noted in table 8.

(11). Finally, prioritizing of each option was performed according to the value of options (Table 9).

As can be seen in Table 9, $A_9 > A_6 > A_5 > A_8 > A_4 > A_3 > A_2 > A_1 > A_7$ with A_9 as the most ideal and A_7 as the least proper options.

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Determination the significance of the environmental impacts in zarshoran gold mine

Determination the significance of the environmental impacts has been always a challenging issue in EIA process. In this regard, 40 negative impacts of gold ore processing were extracted (Table 10).

The selected environmental impacts from gold ore processing is derived from Iranian Leopold matrix. The classification of this matrix has been done with numbers -1 to -5 into 4 classes (Table 11).

Table 3: Normalized values of input weights for locational options

	distance from the mine	closeness to residential areas	impact on surrounding ecosystem	vulnerability to flood and earthquake	access to water and electricity	accesvs to vehicles	unit security	supply of human resources	closeness to agricultural fields	proper topographical situations	access roads
Criteria weight	0.081	0.1162	0.116	0.1162	0.058	0.0581	0.0465	0.0581	0.1162	0.1162	0.1162

Table 4: Weighted normalized data of the locational options.

locational option \ impact type	negative	negative	negative	negative	Positive	positive	positive	positive	negative	positive	positive
A_9	0.04	0	0.01	0	0.02	0.02	0.02	0.02	0.01	0.06	0.05
A_8	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.02
A_7	0.01	0.1	0.05	0.05	0.02	0.02	0.02	0.02	0.05	0.06	0.05
A_6	0.04	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05
A_5	0.01	0	0.02	0.01	0.01	0.01	0.01	0.01	0.05	0.06	0.01
A_4	0	0	0.01	0.03	0.01	0	0.01	0.01	0	0	0.01
A_3	0.03	0.06	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.04	0.05
A_2	0.03	0	0.07	0.07	0.02	0.02	0.01	0.02	0.06	0.02	0.05
A_1	0.04	0	0.07	0.07	0.02	0.02	0.01	0.02	0.06	0.02	0.05

Table 5: The maximum and minimum values of locational options

	distance from the mine	closeness to residential areas	impact on surrounding ecosystem	vulnerability to flood and earthquake	access to water and electricity	access to vehicles	unit security	supply of human resources	closeness to agricultural fields	proper topographical situations	access roads
Maximum	0.03552	0.096	0.06506	0.066	0.0249332	0.0243	0.022881	0.022912	0.0613	0.059	0.046004
Minimum	0	0	0.01301	0	0.0074799	0.0049	0.006864	0.006874	0	0	0.009201

Table 6: The ideal and non-ideal values

	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11
ideal	0	0	0.01301	0	0.0249332	0.0243	0.022881	0.022912	0	0.059	0.046004
Non-ideal	0.03552	0.096	0.06506	0.066	0.0074799	0.0049	0.006864	0.006874	0.0613	0	0.009201

Table 7: Matrix for distance from ideal and non-ideal values

	A9	A8	A7	A6	A5	A4	A3	A2	A1
Distance from ideal for each option	0.0376	0.0685	0.1248	0.0580	0.0689	0.0843	0.0861	0.1140	0.1160
Sum of distance from non-ideal	0.0248	0.0140	0.0070	0.0198	0.0183	0.0181	0.0081	0.0122	0.0122

Table 8: Similarity index

	A9	A8	A7	A6	A5	A4	A3	A2	A1
Similarity index for each option	0.8073	0.6330	0.4021	0.7085	0.6624	0.6147	0.5112	0.4922	0.4874

Table 9: prioritizing of options

A9	A6	A5	A8	A4	A3	A2	A1	A7
0.8073	0.7085	0.6624	0.6330	0.6147	0.5112	0.4922	0.4874	0.4021

Table 12 carries the available criteria from national and international references. These include impact nature, magnitude, spatial extent, and duration as main criteria [15-19] and probability of occurrence, ease of implementing mitigation measures as complementary criteria.

Results of sensitivity analysis for SAW model is delivered in figure 1.

After the options were outranked, the values are classified into classes: 1-10 having very high impacts (VH), 11-20 having high impacts (H), 21-30 having medium impacts (M), 31-40 having low impacts (L). Results of this model is given in table 13.

Conclusions

The achievements of current study could be summarized as follows:

In order to locate the dumping site for tailings, prioritizing of locational options was performed using TOPSIS technique. Prior to this, the decision matrix is constructed after the criteria and their weights are determined.

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Determination of environmental impacts significance is performed by specifying the value of each option in each criterion and determination of weight for each criterion before constructing a matrix providing the raw data for decision making techniques.

Table 10: Project activity- environmental parameters.

	Project activities–environmental factors
A1	Asphalting and widening the access road to the site-soil erosion
A2	Asphalting and widening the access road to the site-air pollution
A3	Asphalting and widening the access road to the site-sound pollution
A4	Asphalting and widening the access road to the site-plants
A5	Asphalting and widening the access road to the site-possessions
A6	Soil excavation and embankment-soil erosion
A7	Soil excavation and embankment-changes in ground morphology
A8	Soil excavation and embankment- quantity of ground and surface water
A9	Soil excavation and embankment-quality of ground and surface water
A10	Soil excavation and embankment-air pollution
A11	Soil excavation and embankment-plants
A12	Soil excavation and embankment-ecosystem habitats
A13	Soil excavation and embankment-social acceptance
A14	Transportation-sound pollution
A15	Construction of gable frames- changes in ground morphology
A16	Construction of gable frames-ecosystem habitats
A17	Establishment of tailings dump, secondary dump, and complementary dump- soil erosion
A18	Establishment of tailings dump, secondary dump, and complementary dump- quantity of ground and surface water
A19	Establishment of tailings dump, secondary dump, and complementary dump- quality of ground and surface water
A20	Establishment of tailings dump, secondary dump, and complementary dump- vegetation cover
A21	subsurface utilities- changes in ground morphology
A22	subsurface utilities- soil contamination
A23	Device installation- sound pollution
A24	Worker's labor-fauna
A25	Landscaping- changes in ground morphology
A26	Extraction of gold- quantity of ground and surface water
A27	Extraction of gold- soil contamination
A28	Transportation of ROM to the pilot site- Safety
A29	Collection and dump of input soil- quantity of ground and surface water
A30	Collection and dump of input soil- soil contamination
A31	Collection and dump of input soil- ecosystem habitats
A32	Collection and dump of input soil- diseases
A33	Activity of crushing unit- quantity of ground and surface water
A34	Activity of crushing unit- sound pollution
A35	Activity of crushing unit- air pollution
A36	Crushed rocks dump-soil contamination
A37	Crushed rocks dump- safety
A38	Activity of grinding unit up to second preparation tank-air pollution
A39	Activity of grinding unit up to second preparation tank-sound pollution
A40	Activity of cyanidation unit up to carbon recovery and providing the product-safety and security

Table 11: Classification of Leopold matrix

-3	High	-1	low
-4, -5	Very high	-2	medium

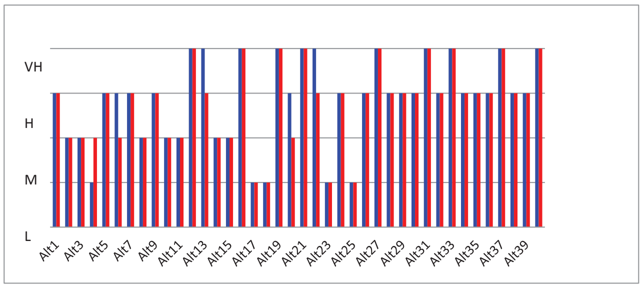

Figure 1: Sensitivity analysis for SAW model.

Table 12: Assessing the environmental criteria in international references.

Evaluation criteria / researchers	(Antunes et al.2001)	(Bojórquez-Tapia et al., 1998)	(Clark et al., 1983)	(Duinker and Beanlands, 1986)	(Gómez-Orea, 1999)	(Lawrence, 2003)	Repetition of criterion in different methods
magnitude	*	*		*	*	*	5
spatial extent	*	*		*	*	*	5
duration		*	*	*	*	*	5
synergism		*			*		2
cumulative impacts		*		`	*	*	3
conflict		*		*			2
mitigation measure		*			*	*	3
sensitivity of resources	*						1
time framework	*						1
Vulnerable population	*						1
Positive/ negative			*		*		2
Reversibility			*		*	*	3
Direct and indirect			*		*	*	3
probability of occurrence				*			1
Ensure the prediction of impact				*			1
existence of compatible values				*			1
Being periodic					*		1
repetition						*	1
people and official priorities						*	1
level of risk and uncertainty						*	1

Subsequently, SAW, TOPSIS, and ELECTRE-TRI methods were applied to classify the options. Sensitivity of each method was analysed and revealed that sensitivity of TOPSIS is maximum (20%) and ELECTRE-TRI has the minimum

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Table 13: Classification of TOPSIS results according to the suggested model.

Classified values	Numerical values	options	Classified values	Numerical values	options
VH	0.52	A21	M	0.83	A01
H	0.69	A22	L	0.93	A02
L	0.93	A23	L	0.94	A03
H	0.64	A24	M	0.86	A04
L	0.97	A25	M	0.86	A05
M	0.77	A26	M	0.79	A06
VH	0.2	A27	M	0.85	A07
M	0.77	A28	L	0.89	A08
H	0.65	A29	H	0.72	A09
H	0.57	A30	L	0.88	A10
VH	0.23	A31	`	0.86	A11
M	0.75	A32	VH	0.29	A12
VH	0.21	A33	VH	0.39	A13
M	0.77	A34	M	0.81	A14
H	0.67	A35	L	0.97	A15
H	0.56	A36	VH	0.34	A16
VH	0.28	A37	L	0.94	A17
H	0.62	A38	L	0.99	A18
H	0.63	A39	VH	0.25	A19
VH	0.05	A40	H	0.7	A20

sensitivity (5%). In other words, ELECTRE-TRI has higher potential ability to determine the environmental impacts significance.

References

1. Abedi HA (2009) Fars, 2009, “Locating and capacity analysis of sugar plant in Kermanshah”, Agricultural and development economics journal 17: 68.

2. Gordon MR (2005) “Tailings management in gold plants.” Journalof Hydro-metallurgy 78: 1-2.

3. Steven G.Vick (1984) Planning, Design, and Analysis of Tailings Dams, John Wiley.

4. Phillips, Jason (2012) *Resources, Conservation & Recycling.* 63: 17-25.

5. Shepard RB (2005) Quantifying Environmental Impact Assessment Using Fuzzy LogicPublisher: Springer; 1st edition. Link: https://tinyurl.com/y8txskcw

6. Monavari (2008) Environmental Impact Assessment, Mitra Publications, 2nd edition.

7. Smarty (South Africa) Minerals Investment (Pty) Ltd (2018) Final EIA/EMPr Report. Application for Mining Right, EA, WML and WUL for Copper Mine near Musina. Link: https://goo.gl/JM2jcg

8. Edraki, Mansour, Baumgartl, Thomas, Manlapig, et al. (2014) Designing mine tailings for better environmental, social and economic outcomes: a review of alternative approaches. Journal of Cleaner Production 84: 411-420. Link: https://tinyurl.com/ybhm8nks

9. NolbertoMunier (2004) Multicriteria Environmental Assessment A Practical Guide. Kluwer Academic Publishers. Link: https://goo.gl/zQb9TP

10. Kahraman C (2008) Multicriteria decision making methods and fuzzy sets. Springer. 16: 1-18. Link: https://goo.gl/7CksGT

11. Cheng SK (2000) Development of a fuzzy multi-criteria decision support system for municipal solid waste management, in graduate studies and research, university of Regina. Link: https://goo.gl/qXz5MW

12. Nesteand J, Timo P. Karjalainen (2013) A literature review – The use of multi-criteria decision analysis in Environmental Impact Assessment,Annex 7.2.5. Inception report B1B Report on the use of MCDA in EIA and SEA. 22 pages. Link: https://goo.gl/FP5Qjm

13. Dezfouli AK (2008) Theoretical principles of fuzzy groups and their application in modeling hydraulic engineering problems, Publications of Amirkabir University Jahad.

14. Pourasghar M (2009) Multicriteria decision making, Tehran University Press.

15. Malekmohammadi B, Zahraei B, Karachian R (2008) Outranking the results of multi-objective optimization model for reservoirs using ELECTRE-TRI, Proceedings of 3rd Iranian conference on water resources management, Tabriz, Iran.

16. Antunes P, Santos R, Jordao L (2000) The application of Geographical Information Systems to determine environmental impact significance. Environ Impact Asses Rev 21: 511-535. Link: https://goo.gl/55Dsm4

17. Bojórquez-Tapia LA, Ezcurra E, García O (1998) Appraisal of environmental impacts and mitigation measures through mathematical matrices. Journal of Environmental Management 53: 91–99. Link: https://goo.gl/oEfJ1A

18. Gómez-Orea D. Evaluación (1999) de ImpactoAmbiental. In: Mundi-Prensa, editor. Uninstrumentopreventivopara la gestiónambiental. Editorial Agrícola Española S.A.84-85441-51-6.

19. Pars Kani Engineering Company (2009) A quick report of Zarshoran gold extraction. Environmental Research center of TarbiatModares University.

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