Prioritization Of Plants In The Choghart Iron Ore Mine Reclamation Project By Promethee Method And Comparison With The Results Of The Fuzzy Topsis Method (Case Study: Choghart Iron Ore Mine)

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ABSTRACT:

Mining operations as an activity play a role in environmental changes, which by utilizing new technologies, it is possible to decrease and minimize the environmental damage, while exploiting them principally. The reclamation of the mine is the most important plan to restore the mined land to the original state, and then to restore the area in different ways. When a case study was conducted in Choghart iron ore mine, the species were selected according to the suitability with initial factors of the reclamation plan including the type of mined land reuse, the climatic conditions, and the nature of the soil. Then, the secondary factors (criteria) were determined, and the decision matrices were obtained based on the questionnaires completed by the experts, and the plant species were prioritized based on the regional spectacle criteria, resistance against disease and insects, power and growth, access to plant species, economic efficiency, soil conservation and water supply and prevention of various types of pollution, by multi-criteria decision-making methods. It should be noted that the weights of the criteria are compared by Fuzzy AHP method and general prioritization of the options by PROMETHEE and Fuzzy TOPSIS methods. The most suitable plant species in the mining range and tailings dam obtained in order of priority in PROMETHEE method are tamarisk (0.78), palm (0.11), eucalyptus (0.04) and pine (0.85), respectively.

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Selection of plant species, Choghart iron ore mine, Fuzzy AHP, PROMETHEE, Fuzzy TOPSIS, tamarisk.

1. INTRODUCTION

Reclamation, in its common sense, is the preparation of mined land for reuse, and it is mostly related to surface mines. The reclamation of the mine as an integral part of the overall design of the mine should be considered from the very early stages of mining operations. The aim of restore is to preserve the environment of the region and create a better life in the region's climate. In general, the site of the mine should be reclaimed so that the reuse of the land and the geological structural of the mining site or the site environment be compatible (Soltanmohammadi et al, 2010). The most commonly used methods for the reclamation of contaminated land are based on expert view of geochemical, aquatic, ecological and environmental engineers and have three stages: removing the source of pollution, not using the mine site, reclamation of the site (Alavi et al., 2011). For reclamation of a mine, for any future use of affected land and conservation of the environment, selecting and planting plant species is one of the important steps (Xia et al, 2007). Restoring vegetation in destroyed lands can have a significant impact on reducing erosion and land degradation. The effect of plants on their cultivating soil causes physical and chemical changes in soil (Tavili, 2001). Selective plants should be resistant to adverse soil conditions in unsuitable mined areas, which play a fundamental role in reclamation of mined land (Haque et al, 2009). The acidity suitable for plant growth is 6.5 to 7.5 (Akbari et al, 2007). Native plant species have the best adaptation to the climatic conditions of the area, and if fertilizer is added, the growth conditions become better (Redente and Baker, 1996). In general, it can be said that the maintenance of the properties and nutrient reserves in the soil is heavily dependent on vegetation (Belsky and Canham, 1994). Tafi (2006), Creek and Kruger (2007) evaluated the factors limiting the growth of plants on mined soil. Cairns (1982), Erington (2001), performed researches for reuse of mined land. The impact of plant cultivation on mined land was investigated by Alexander (1996). Akbari et al, (2007) identified the type of

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reuse of mined land. Sultan Mohammadi et al. (2008) examined the possible uses of mined lands by methods such as AHP ELECTR and TOPSIS. Osanloo and Parsaii (2004) conducted a study on the reclamation of Sarcheshmeh copper mine.

Bangian and Osanloo (2008) conducted a selection of plant species for the reclamation of Sungun copper mine through hierarchical analysis. Alavi et al, (2011) obtained the best plant species by fuzzy AHP method for the reclamation of Sarcheshmeh copper mine. Mishra et al, (2003) surveyed the effects of eucalyptus cultivation on soil during periods of 3, 6 and 9 years, and found that due to the cultivation of this species, acidity and electrical conductivity decreased and organic matter, total nitrogen, available phosphorus, calcium, magnesium and potassium exchangeable ions in soils increased. Rasooli (2004), reported that cultivation of tamarisk on the margin of the Tehran-Qom highway, increased the amount of nitrogen, phosphorus, potassium and soil electrical conductivity. Considering that up to now, the selection of plant species in a place has not been carried out using a PROMETHEE method, therefore, in this paper, PROMETHEE approach was used to prioritize and select the most suitable plant species for the reclamation of Choghart iron ore. PROMETHEE method is well received by academics and researchers, and many articles have been written using this technique (Behzadian, et al, 2009). Based on studies in which the options are not matched (e.g., one option is better for a benchmark, and another option based on another criterion, which is also applicable in this research), PROMETHEE application like other multi-criteria methods such as hierarchical analysis, ELECTRE, etc is useful for comparing the alternatives (Soltanmohammad et al, 2008). However, PROMETHEE method is advantageous in comparison with methods such as hierarchical analysis, because hierarchical analysis has the probability of human error and when the number of criteria and options is high, due to increased interactions, calculations are tedious and time-consuming (Niknafs et al, 2010). Also, the hierarchical approach is limited on a scale of 1 to 9, including its weaknesses (especially when data is small) (Zak and Sawicka, 2010). The limitation of the disadvantage is that it does not

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provide an approach for weighing the criteria and leaves this to the decision maker (Macharis et al, 2007).

In this paper, we first discuss the theoretical foundations on how to select and prioritize plant species in a mine reclamation plan. Then, explanations are presented in the case of Choghart iron ore. Fuzzy logic and multi-criteria decision-making methods are explained. In order to select the best plant in the reclamation of Choghart iron ore, PROMETHEE and fuzzy TOPSIS methods are used, and their results are compared. As mentioned above, in a PROMETHEE approach, we did not come up with an approach for weighting the criteria, so for this purpose, the fuzzy hierarchical analysis method that yields acceptable results is used to weigh the criteria. In the following, a brief description of this method is provided.

2. THEORETICAL FOUNDATIONS

2.1.The Importance of Selecting Plant Species in the reclamation of the Mine

In a mine reclamation, in order to reuse the mined land, planting and creating landscape for the region is a necessary step for achieving reclamation plan goals. As a result, selection of plant species is one of the main steps in achieving the objectives of the reclamation plan. The selection of superior plant species in each regeneration program has several benefits such as maintaining the health and rehabilitation of the environment, the prospect of the region, the economic benefits, the welfare of the people of the region, reducing soil and climate pollution, underground water storage, preventing soil erosion (Bangian and Osanloo, 2008). The factors influencing the selection of plant species are divided into primary and secondary groups. The main factors are those factors that the selected plant species should certainly have fit and coordinate with them. However, sub-factors are factors that include the conditions of the region and the selected plant species will be prioritized relative to each other based on them..

2.2 Selection of Plant Species Based on the Primary Factors

Plant varieties should be coordinated and compatible with the original factors. As a result, at this stage, only the species that are compatible with the type of reuse of the land will

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pass to the next step. In the next stage, the existing species are examined in relation to the climatic conditions of the area, and the rest of the options are rejected. The quality and the type of the soil of the region as a third factor of the primary factors, rejects some of the options among selected species based on the first and second factors.

2.3 Prioritization of Plant Species Based on Secondary Factors

The secondary factors (criteria) are:

Prospect of the region, resistance to disease, human infringement, power and growth, compatibility with other species in the region, economic efficiency, insect resistance, soil conservation, water supply, prevention of various types of contaminants, access to plant species

3. CASE STUDY

The study area is located in Bafq, 120 km south-east of Yazd, at an altitude of 927 meters above sea level. Choghart apatite iron mine is located in the Anarak- Bafq -Kerman belt in the east of central Iran. Choghart mine is located 12 km northeast of Bafq city, 125 km south-east of Yazd city and 75 km southwest of Behabad city and on the margin of the Dareh Anjir desert. The mine has a geological reserve of 207 million tons and its initial elevation is 1286 meters. The mining capacity of the mine is estimated at 177.2 million tons, of which 95.6 million tons due to high levels of iron and low phosphorus, after being crushed directly are consumed by steel factories, and the remainder should be sent to processing plant for beneficiation. Choghart is the only mine supplier of Isfahan iron and steel plant and has higher iron grades than other reserves in the region. In this mine, magnetite is the main mineral, and apatite is a disturbing mineral. Mining operations are carried out as surface mining using electric shovel with a volume of 7 cubic meters and trucks with capacity of 32 and 65 tons. The amount of iron, sulfur and phosphorus in the soil is high (Kasmaee et al, 2010).

4. RESEARCH METHOD

4.1 Decision-making:

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Multi-criteria decision-making models have been developed to help make the right and scientific decision, and are divided into two groups of Multi Objective Decision Making (MODM)(uncountable) and Multiple Attribute Decision Making (MADM) (countable) models. Multi-objective models (such as ideal planning and data panels) are often used to design, define target, and simultaneously optimize multiple targets (Momeni, Mansour, 2008, Taherkhani, Mahdi, 2007). Multi attribute models are used to evaluate, prioritize, and select among different options based on specific (and in some cases inconsistent) criteria, usually in accompany of weighting (Chou, et al, 2004, Brans and Mareschal., 2005). These criteria usually explain the features of options. in fact, decision making refers to how to choose the best option among possible options, so that the selected options can be most profitable and to bring success.

4.2 Fuzzy Logic

Fuzzy logic is a very important type of logic that was introduced by Zadeh in 1965 and seriously contrasted with the Aristotelian binary logic. Fuzzy theory provides grounds for reasoning, inference, control, and decision making in ambiguous conditions and transforms qualitative judgments into quantitative numbers (Zadeh, 1965). Zadeh (1965) proposed the theory of fuzzy sets as a method for modeling in ambiguity and lack of certainty. The regular set is of two values and the membership function can only take two values of 0 or 1. That is, it is either zero (the employee is not a member of the set) or one (the employee is a member of the set). However, in the fuzzy set, degrees between 0 and 1 are introduced. The degree of membership is determined by fuzzy logic. Between two states of zero and one, a degree of membership of an element of a set is determined. Fuzzy is a spectrum between black and white, or gray, that allows for modeling in the epidemic uncertain environments of the real world (Zadeh, 1965). Zadeh, with this theory, expressed the uncertainty caused by the ambiguities of human thoughts. The main benefit of this theory is the ability to provide data that is uncertain. The application of fuzzy sets in decision-making problems is one of the most important and efficient applications of this theory in comparison with the theory of classical collections. In fact, the fuzzy

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decision theory attempts to model the ambiguity and inherent uncertainties in the preferences, goals, and constraints in decision-making. Human thoughts are associated with uncertainty and this uncertainty affects decision making. For this reason, fuzzy decision-making methods are used.

4.3 Fuzzy Analytic Hierarchy Process (F. AHP)

Fuzzy Analytic Hierarchy Process is one of the multi-attribute decision-making methods. This method was suggested by Thomas L. Saaty originally from Iraq, in the 1970s (Saaty, 1980). This method, like what is done in the human brain, analyzes the issues. The analytic hierarchical method helps decision makers to set priorities based on their goals, knowledge and experience, in a way that fully considers their feelings and judgments. In order to solve the decision making problems in this way, we must define and explain the problem with precision and with all the details, and draw the details in a hierarchical structure.

The algorithm of this method is as follows (Momeni, 2008):

1. Drawing a hierarchical structure

2. Formation of the pair wise comparative matrix shown in Table 1.

	C1			C2			C3			C4			C5			C6			C7		
C1	1.0	1.0	1.0	0.6	0.8	1.3	0.6	0.8	1.3	0.7	1.4	3.0	1.0	2.3	4.5	0.6	0.8	1.3	0.6	0.8	1.3
C2	0.8	1.3	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	3.0	1.4	3.0	4.5	1.0	1.0	1.0	1.0	1.0	1.0
C3	0.8	1.3	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	3.0	1.4	3.0	4.5	1.0	1.0	1.0	1.0	1.0	1.0
C4	0.3	0.7	1.4	0.3	0.6	1.0	0.3	0.6	1.0	1.0	1.0	1.0	0.6	1.7	3.5	0.3	0.6	1.0	0.3	0.6	1.0
C5	0.2	0.4	1.0	0.2	0.3	0.7	0.2	0.3	0.7	0.3	0.6	1.7	1.0	1.0	1.0	0.2	0.3	0.7	0.2	0.3	0.7
C6	0.8	1.3	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	3.0	1.4	3.0	4.5	1.0	1.0	1.0	1.0	1.0	1.0
C7	0.8	1.3	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	3.0	1.4	3.0	4.5	1.0	1.0	1.0	1.0	1.0	1.0

Table 1. Dual comparison matrix of criteria in the method F.AHP

3- Determination of the relative weights respectively observed in the following formulas; The result is given in Table 2.

Fuzzy multiplication =$\otimes$, (1)

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= Sum of columns of fuzzy summation of row numbers,

= fuzzy sum of numbers in each row

, (2)

= Magnitude M2 (first S) to M1 (second S)

V(S1>= S2=(	0.8 69	V(S1>= S3=(	0.8 69	V(S1>= S4=(	1.0 00	V(S1>= S5=(	1.0 00	V(S1>= S6=(	0.8 69	V(S1>= S7=(	0.8 69
V(S2>= S1=(	1.0 00	V(S2>= S3=(	1.0 00	V(S2>= S4=(	1.0 00	V(S2>= S5=(	1.0 00	V(S2>= S6=(	1.0 00	V(S2>= S7=(	1.0 00
V(S3>= S1=(	1.0 00	V(S3>= S2=(	1.0 00	V(S3>= S4=(	1.0 00	V(S3>= S5=(	1.0 00	V(S3>= S6=(	1.0 00	V(S3>= S7=(	1.0 00
V(S4>= S1=(	0.8 31	V(S4>= S2=(	0.6 79	V(S4>= S3=(	0.6 79	V(S4>= S5=(	1.0 00	V(S4>= S6=(	1.6 37	V(S4>= S7=(	0.6 79
V(S5>= S1=(	0.5 76	V(S5>= S2=(	0.4 04	V(S5>= S3=(	0.4 04	V(S5>= S4=(	0.7 64	V(S5>= S6=(	1.5 49	V(S5>= S7=(	0.4 04
V(S6>= S1=(	1.0 00	V(S6>= S2=(	1.0 00	V(S6>= S3=(	1.0 00	V(S6>= S4=(	1.0 00	V(S6>= S5=(	1.0 00	V(S6>= S7=(	1.0 00
V(S7>= S1=(	1.0 00	V(S7>= S2=(	1.0 00	V(S7>= S3=(	1.0 00	V(S7>= S4=(	1.0 00	V(S7>= S5=(	1.0 00	V(S7>= S6=(	1.0 00

Table 2. Relative weights of criteria relative to each other

, (3)

= anormalized weight (minimum of the numbers of each row according to formula 3) which is obtained by minimizing the relative weights in each row, which are normalized using formula 4 and the weights of each criterion are listed in Table 3.,

, (4)

Minimum	Normalized	weight
0.869	0.146	S1
1.000	0.168	S2

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1.000	0.168	S3
0.679	0.114	S4
0.404	0.068	S5
1.000	0.168	S6
1.000	0.168	S7

Table 3 . The final weights of the criteria

Each of the weights is normalized by dividing to the sum of the total columns of minima, and here the weight of the criteria is obtained.

4. Determining the final weight of each option and prioritizing (in case of comparing the options according to the weight of the above criteria)

A1= (A1 to C1 × C1 to GOAL) + (A1 to C2 × C2 to GOAL) + (A1 to C3 × C3 to GOAL)............. , (5)

4.4 Fuzzy Technique for Order-Preference by Similarity to Ideal Solution (F. TOPSIS)

It is one of Multi-attribute decision-making methods. This method was originally presented by Yoon and Hwang (Hwang and Yoon, 1981). The basic concept of this method is that the selected option should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. Chen (2000), developed TOPSIS in fuzzy environment. The algorithm of this method is as follows (Momeni, 2008):

1. The decision making matrix is formed as Table 4: Fuzzy numbers are defined for the expression of the linguistic variables in the decision matrix (1 to 9) which are very low [1, 2, 3], low [2, 3, and 5], moderate [3, 5, and 7], high [5, 7 and 9] are very high [7, 9 and 9]. For example, the following table is a decision making matrix of Fuzzy TOPSIS method that was obtained from questionnaires (Alavi et al, 2011).

	C1	C2	C3	C4	C5	C6	C7

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A1	7,9,9	5,7,9	3,5,7	3,5,7	5,7,9	3,5,7	7,9,9
A2	7,9,9	3,5,7	5,7,9	5,7,9	7,9,9	5,7,9	3,5,7
A3	5,7,9	5,7,9	2,3,5	3,5,7	2,3,5	3,5,7	5,7,9
A4	3,5,7	5,7,9	7,9,9	7,9,9	3,5,2	5,7,9	5,7,9

Table 4. Decision matrix in Fuzzy TOPSIS method

2. The weight of the criteria is determined. Weight was obtained by The Fuzzy AHP method by Formulas 1 to 4 according to Table 5.

C1	C2	C3	C4	C5	C6	C7
0.146	0.168	0.168	0.114	0.068	0.168	0.168

Table 5. Weights of criteria

3. Undimensioning the decision matrix: For the positive criterion, the highest number (+ Cij) is selected in each column, then all droves (aij, bij, cij) are divided into it. For the negative criterion, the lowest number for each column is selected and divided into all droves. (With the fact that in the denominator, the lower bound and the upper bound are replaced). Because in this research, all the criteria are positive, the formulas are based on a positive criterion.

, (6)

4. Formation of a dimensionless weighted matrix

(7) ij= ij (.)ij

5 -Determination of Ideal Fuzzy and Anti-Ideal Fuzzy) Vij): The ideal solution for the positive criterion, the maximum of the third component, is obtained in each column. An anti ideal solution for a positive criterion, the minimum of the first component ,is obtained in each column ,calculated by formulas 7 and 8.

, (8)

, (9)

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6. Determination of the distance from the ideal and anti-ideal solution shown in Tables 6 and 7, which are calculated from formulas 10 and 11.

= , (10)

= , (11)

فاصله	C1	C2	C3	C4	C5	C6	C7
d(A1,A+ (	0.024	0.048	0.081	0.055	0.020	0.081	0.022
d(A2,A+ (	0.024	0.081	0.048	0.033	0.009	0.048	0.081
d(A3,A+ (	0.054	0.048	0.108	0.055	0.044	0.081	0.048
d(A4,A+ (	0.090	0.048	0.022	0.015	0.044	0.048	0.048

Table 6. Distances from ideal solution

Distance	C1	C2	C3	C4	C5	C6	C7
d(A1,A(-	0.113	0.081	0.064	0.033	0.040	0.048	0.101
d(A2,A(-	0.113	0.058	0.098	0.055	0.048	0.081	0.048
d(A3,A(-	0.090	0.081	0.034	0.033	0.014	0.048	0.081
d(A4,A(-	0.054	0.081	0.120	0.069	0.014	0.081	0.081

Table 7. Distances from anti-ideal solution

7- Determination of similarity index (coefficient of closeness)

, (12)

8. Prioritization of options: was done based on the magnitude of the similarity index.

4.5 Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) Method

Since the purpose of this paper is to introduce and use the PROMETHEE method in the field of reclamation of surface mines, the steps of the PROMETHEE method with its application for selection of plant species are presented in this case study. Halvani et al.

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(2009) stated that the PROMETHEE methods including PROMETHEE-I partial ranking and PROMETHEE-II full ranking have been developed by Brans and Vincke (1985), (Halouani et al, 2009). This method which is used in the analysis of multi-criteria issues, is conceptually and practically easier in comparison to other methods (Albadavi et al, 2007). The PROMETHEE weakness is that it does not provide an approach for weighting the criteria and leaves this to the decision maker (Macharis et al, 2007). In the PROMETHEE method, ranking of options is based on paired comparisons, which is one of the multi-criteria decision-making methods (Mohaghar and Mostafavi, 2007). This method is used to evaluate and prioritize discrete options and select the best option based on multi criteria (with different measurement scales) (Chou et al, 2004). In using PROMETHEE, there is a limitation to compensate the weakness of a criterion or the strength of other criterion, and therefore an ideal option should obtain the minimum of all criteria. In addition, the PROMETHEE method can easily apply criteria with different measuring scales (no need to match the criteria scale) and, in accordance with the information and the standard scale, defines separate six- functions, therefore, in multi criteria decision-making in which criteria have different scales of measurement, it is usually a strength point for decision maker.

4.6 Selection of plant species based on primary and secondary factors (criteria) using PROMETHEE method)

4.6.1 Type of Reuse of Land: Several cases are considered for reuse of mineral lands, that depending on the conditions, one of them is selected, including fields, grasslands and pastures, forest nursery, lake and water catchment area, sports ground, forestry, residential complex, park and free space, commercial use, industrial use, wildlife habitat, educational use (Soltanmohammadi et al., 2010).

4.6.2 Climate: Choghart mineral zone has a dry desert climate and very hot, desert climate and very little moisture. The city of Bafq, with an average annual precipitation of 53 mm, is one of the driest cities in Yazd province.

4.6.3 Nature of soil: The amount of iron, sulfur, phosphorus and salt in this area is high.

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Considering the main factors and adaptation of different species of plants to the conditions in the area of Choghart iron ore mine, 4 superior and compatible species of vegetation were selected including: eucalyptus, palm, pine, tamarisk. Then, according to the seven criteria of prospect (C1), resistance to disease and insects (C2), the mode and power of growth (C3), access to plant species (C4), economic efficiency (C5), soil conservation and water reservoir (C6) and pollution prevention (C7) the most suitable option is selected by PROMETHEE method, which was obtained by the following steps.

The values of the performance of qualitative criteria are obtained using expert opinion and using the five point Likert spectrum method as shown in Table 8.

Numerical values	linguistic variable
1	Very low
2	low
3	Medium
4	high
5	Very high

Table 8. Converting the qualitative linguistic importance to a quantitative degree (pooya et al, 2012)

In this way, decision makers are asked to express their decision regarding the evaluation of options based on the qualitative criterion and complete the questionnaires according to Table 9.

1- Weight of the criteria: weight vector (0 to 1) were calculated using the fuzzy AHP method from Table 9, according to formulas 1 to 4, which are shown below.

(C1=0.146, C2=0.168, C3=0.168, C4=0.114, C5=0.068, C6=0.168, C7=0.168)

Very much	Very	Medium	Little	Very low	Criterion-Importance
	•				Landscape area
•					Resistance to disease and insects
•					How and Growth

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		•			Access to plant species
			•		Economic returns
•					Soil protection and water storage
•					Preventing pollution

Table 9. questionnaire on the importance of criteria in relation to each other with consideration of purpose

2. Formation of the evaluation table: The evaluation matrix of options (alternatives) in relation to the criteria is made up of questionnaires filled out by the relevant experts. The evaluation table is the starting point for the PROMETHEE method. In this table, the options are evaluated based on different criteria (Macharis et al, 2007), which are specified in Table 10.

C7	C6	C5	C4	C3	C2	C1	
5	3	4	3	3	4	5	A
3	4	5	4	4	3	5	B
4	3	2	3	2	4	4	C
4	4	2	5	5	4	3	D

Table 10. Options (alternative) evaluation matrix

3. Calculation of the priority function: When two options A ϵ a,b are compared the results of these comparisons should be expressed based on a preference. In PROMETHEE method, the priority function of each criterion is often determined by the nature of each criterion and decision-maker's view (Albadavi et al, 2007). The preference function converts the difference between the values of the two options in a particular criterion, which changes from 0 to 1, (Bogdanovich et al, 2012).

$$Pj(a,b)=Fj[dj(a,b)] , \quad a,b \in A \qquad , (13)$$

$$dj(a,b)=fj(a)-fj(b) \qquad , (14)$$

$$0<=Pj(a,b)<=1 \qquad , (15)$$

For each option a, pj is calculated for option b, which is a function of the deviation between a and b, and is the difference between fj (a)and fj (b), which is entered in Table

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9. fj (a) is the value of criterion j in option a that is contained in the decision matrix of the evaluation of options in Table 9. The basis of the PROMETHEE method is pair wise comparison. In this case, the numerical difference between the options in each of the criteria is considered, so that the decision maker for small differences, allocates a small preference to a better option. If the difference is small between the two, the two options are assumed same in terms of that criterion, and if the differences are large, the preference and higher scores will be allocated to the better option. Pair wise comparison matrix of options is prepared from the comparison of the two options to each other and to each criterion. In this paper, since all the criteria are positive, so the larger numbers (fj(a)), in pairwaise comparison of options, is considered as number 1 (one) and the smaller and equal numbers to (fj(b)), as the number 0 (zero) (Safari et al, 2012)) and (a) fj- fj (b) is shown in Table 11 as Pj.

0.168	0.168	0.068	0.114	0.168	0.168	0.146	Weight-Criterion
C7	C6	C5	C4	C3	C2	C1	
1	0	0	0	0	1	0	A-B
0	1	1	1	1	0	0	B-A
1	0	1	0	0	0	1	A-C
0	0	0	0	1	0	0	C-A
1	0	1	0	0	0	1	A-D
0	1	0	1	1	0	0	D-A
0	1	1	1	1	0	1	B-C
1	0	0	0	0	1	0	C-B
0	0	1	0	0	0	1	B-D
1	0	0	1	1	1	0	D-B
0	0	0	0	0	0	1	C-D
0	1	0	1	1	0	0	D-C

Table 11. Comparison matrix of options) alternatives

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. Calculation of the overall priority function: In the next step, the matrix of the priority value of the options is formed relative to each other for all criteria according to the weight of the criteria, which finally yields the cumulative preferential index as shown in Table 12.

, (16)

$$\pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j$$

Where (a, b) Π is the sum of P (a,b) for each criterion, and Wj is the weight associated with jth criterion, the larger the value of it, the larger preference has the option (Bogdanovich et al, 2012).

Cumulative preference Index	C7	C6	C5	C4	C3	C2	C1	Criterion
	0.168	0.168	0.068	0.114	0.168	0.168	0.146	Coefficient of importance criteria
0.336	0.168	0	0	0	0	0.168	0	A-B
0.518	0	0.168	0.068	0.114	0.168	0	0	B-A
0.382	0.168	0	0.068	0	0	0	0.146	A-C
0.168	0	0	0	0	0.168	0	0	C-A
0.382	0.168	0	0.068	0	0	0	0.146	A-D
0.45	0	0.168	0	0.114	0.168	0	0	D-A
0.664	0	0.168	0.068	0.114	0.168	0	0.146	B-C
0.336	0.168	0	0	0	0	0.168	0	C-B
0.214	0	0	0.068	0	0	0	0.146	B-D
0.618	0.168	0	0	0.114	0.168	0.168	0	D-B
0.146	0	0	0	0	0	0	0.146	C-D
0.45	0	0.168	0	0.114	0.168	0	0	D-C

Table 12. The matrix of priority values of options (alternatives) relative to each other for all criteria)

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5. Calculation of positive and negative flows:

In the next step, positive outranking flow (output flow) is calculated as follows: (Brans and Vincke, 1985).

, (17)

$$\phi^{+}(a)=\frac{1}{n-1}\sum_{x\in A}\pi(a,x),$$

Which indicates the power and priority of option a relative to n-1 other options. The largest $\Phi^{+}(a)$ means the best option (Omidi et al, 2011). The negative outranking flow (input flow) is also obtained from the following equation (Brans and Vincke, 1985).

, (18)

$$\phi^{-}(a)=\frac{1}{n-1}\sum_{x\in A}\pi(x,a).$$

This flow shows how much other n-1 options are prior to option a. In fact, this is a weakness of option a. The smallest $\Phi^{-}(a)$ means the best option (Omidi et al, 2011). The preferred option matrix in which the original diameter is zero and the numbers above the main matrix's main diameter include the upper numbers of the cumulative preferential index and the lower numbers of the matrix diameter, include the lower numbers of the cumulative preferential index, are shown in Table 13. Therefore, by having and separate investigation of the two flows of $\Phi^{+}(a)$ and $\Phi^{-}(a)$ we perform partial ranking (PROMETHEE I ranking) (Omidi et al, 2011). The problem with this method here is that, for example, in figure 1, if, in comparison of the two options, the positive and negative flows are greater than or lower than next option flows, this method cannot clearly determine the superiority of the options. Of Course in this article there was no problem of this kind.

Output flow Φ^{+}	D	C	B	A	
1.1	0.382	0.382	0.336	0	A
1.396	0.214	0.664	0	0.518	B

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0.65	0.146	0	0.336	0.168	C
1.518	0	0.45	0.618	0.45	D
	0.742	1.496	1.29	1.136	Φ Input flow) -

Table 13. Options (alternatives) preference matrix

1		3	
tamarisk	D	eucalyptus	A
Q+	1.518	Q+	1.1
Q-	0.742	Q-	1.136
2		4	
palm	B	pine	C
Q+	1.396	Q+	0.65
Q-	1.29	Q-	1.496

Figure 1. PROMETHEE I ranking

6- Net flow calculation: For full ranking of options, net flow of ranking for each option must be defined (PROMETHEE II ranking) shown in Table 14 and Figure 2. This flow is the result of the balancing positive and negative ranking flows. A higher net flow indicates a superior option (Omidi et al., 2011). To calculate the net flow, the following relation is used (Brans and Vincke, 1985), which is difference between a positive and negative flows.

$$\phi(a) = \phi^{+}(a) - \phi^{-}(a) \quad , (19)$$

	Ratin g	(Q+)-(Q-)	Q-	Q+	Option

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eucalyptus	3	-0.04	1.136	1.1	A
palm	2	0.11	1.29	1.396	B
pine	4	-0.85	1.496	0.65	C
tamarisk	1	0.78	0.742	1.518	D

Table 14. PROMETHEE general ranking

1		3	
tamarisk	D	eucalyptus	A
Q	0.78	Q	-0.04
2		4	
palm	B	pine	C
Q	0.11	Q	-0.85

Figure 3. PROMETHEE II final ranking

1. CONCLUSION

In this paper, the decision making method for selecting the suitable plant species for the reclamation of Choghart iron ore mine is prepared. Selection of the method of reclamation and the type of plant species is one of the most important parts of the mining project, which requires several criteria to be considered. The fuzzy AHP method was used to obtain the weights, while the PROMETHEE method was used for full ranking of the options. One of the important advantages of the PROMETHEE method can be the transparent effect of each criterion and its weight on the answers, the high efficiency of the algorithm of this method while its simplicity, clarity and reliability, and its foundation based on the importance of the difference in the performance of the two solutions (its distinction from AHP hierarchical structure approach or similarity to the ideal TOPSIS option). This method can carry out the evaluation process on a limited set of limited alternatives, in a partial or complete ranking. As can be seen, the first and second selection of plant species in both PROMETHEE and fuzzy TOPSIS methods are the species of tamarisk and palm. The point that should be mentioned in the fuzzy TOPSIS method is

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that in the weighting of the criteria in the past research figure normalization from 1 to 9 was performed, and the result of the present study in which the weight of the criteria is obtained by hierarchical analysis method is more accurate. However, no significant difference was found in overall outcomes. Finally, in the fuzzy TOPSIS method the points of the species are as follows: tamarisk (0.613), palm (0.608), eucalyptus (0.592) and pine (0.465), and in PROMETHEE method: tamarisk (0.78), palm (0.11), eucalyptus (-0.04) and pine (-0.85).

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