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The Use of VIKOR Method to Set up Place Locating of Processing Plant (Case Study: Processing Plant of South of West Azerbaijan)

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ABSTRACT

Selecting the propriate place of mineral processing plant is one of the most important steps in setting up it. It depends on several factors that make it a subroutine of multi criteria decision making (MCDM) problem. In this research, locating an optimal site for quarries processing plant, using VIKOR method is studied. Three sites were considered for this purpose and criteria such as transportation, water supply, electricity supply, gas supply, distance to markets, the price of land, topography and distance to where personal supplement place for the three possible regions were analyzed. After calculating parameters of VIKOR method, according to the obtained and ranked Q values of 0.8969, 0.0000, 0.1000, respectively for three possible cases of place A1, A2 and A3, case of A2 is selected as best choice.

1. Introduction

Locating the optimal site for the construction of a processing unit is significant multi criteria decision making problem which affects other aspects of human being life such as social,

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political, cultural, commercial, and environmental characteristic of selected area. For this reason, the construction of a processing unit at appropriate place can provide the necessary opportunities for its upstream and downstream industries of the area.

Right site selection could affect all aspects of whole of processing plant project. Considering this problem, the critical factors in this problem are cases such as technical problems, transportation costs of cubes cut from quarry and the traffic due to trucks carrying cubes. Taking account above mentioned reasons, usually these plants are constructed near the relevant mines. due to the significant of selecting optimal site, various research was done. Among the studies which is done in the field of selecting the optimal location for the construction of dimension stone plant, the following studies could be considered.

At first, they developed a model based on mathematical relation and then the main aim and decision factors is introduced. By defining above mentioned factors, it should be presented an objective function which is used to minimizing gap of undesired fuzzy weights from optimum values. Experts suggestion and fuzzy geometric mean considered as base for determining Fuzzy weights. The main aims and limits of problem were also modelled. Safari et al. set up most suitable copper mine mineral processing plant site in Chah-firuz area considering key factor affected selection process by using AHP method [1]. Ataei using AHP method selected the best sit for construction of alumina-cement plant location in East Azerbaijan province of Iran which led to accepted result [2]. Anagnostopoulos et al. analyzed sustainability of water waste treatment site by utilizing Spatial Fuzzy Analytic Hierarchy Process [3]. Esmaeilzadeh et al. explored most suitable method of extraction of dimension stone using FDAHP & TOPSIS techniques which result in best choice and high efficiency in recovery rate [4]. Safari et al. select best site for construction of mineral processing plant by using fuzzy TOPSIS method [5]. Shahsavani et al. used a Monte Carlo- AHP approaches to locate a best place for limestone paper plant located in Kurdistan province in Iran [6]. Haghshenas et al. investigated the selection of an appropriate tunnel supporting system according to the combination of FDAHP method and ELECTRE technique. The weights of the criteria determined by FDAHP, and tunnel supporting system selected by the ELECTRE. The results showed that the rock bolt with reinforced shotcrete system is the most suitable [7]. Lotfian et al. investigated the grey geographic information system (GIS) to find the best area for cement plants located in South Khorasan province, Iran [8]. Zhang and Goh developed multivariate adaptive regression splines and neural network models for prediction of pile drivability [9]. Zhang et al. in 2020 reviewed the applicationof soft computing in underground excavations [10]. Zhang et al. in 2020 investigated the undrained shear strength using extreme gradient boosting and random forest based on Bayesian optimization [11]. Wang et al. 2020 studied on probabilistic stability analysis of earth dam slope under transient seepage using multivariate adaptive regression splines [12]. In addition, numerous studies on the selection of appropriate alternatives using multiple-criteria decision-making (MCDM) and metaheuristic algorithm have been presented. Some of these studies related to the stone industry are given below. In other work, researchers proposed two new models based on multiple linear regression (MLP) and a robust non-linear algorithm of gene expression programming (GEP) to evaluate the performance evaluation of gang saw machines [13].

The paper is organized as follows, in section 2, the studied mines and proposed processing plant sites are investigated. In the next section, the VIKOR technique is used to select the suitable processing plant due to 8 criteria such as transportation, water supply, electricity supply, gas supply, distance to markets, the price of land, topography and distance to where personal supplement place. Finally, in section 4, the results of study are given.

2. Site investigation

West Azerbaijan province is one of the active mineral areas of the country due to the geological structure and reconnaissance surveys which is carried out based on the occurrence of many geological events. There are various types of igneous, metamorphic and sedimentary stones that are also used as dimension stones due to having specific physical properties. These properties mainly include color, granulation, porosity, smoothness, shear strength and abrasion resistance. Specific attention should be paid for determining the quality of dimension stone for stone characteristics such as specific gravity, water absorption percentage, compressive and bending strength of stone and abrasiveness. Therefore, it should be considered that the stone should be uncracked and uniform in appearance, and it should not have any weakness such as cracking, weathering, spots due to harmful minerals, and so on. In terms of number and diversity, this province has many deposits of dimension stones, and among various type of stones, the travertine stones of this province also have good quality. Numerous dimension stone quarries exist in the province but area which selected as case for study located in southern region of the province that named Tekab. The selected mines as case study are located within the urban limit of Takab. Considering potential of area around the city and the large number of active mines of dimension stones, especially travertine mines, this region was selected. The mines which selected to study is presented in Table 1. Photographs of the studied mines are shown in Figure 1.

Table 1
Mines which processing plant should be construct considering their location.

No.	Name	Deposit
1	Takab Choplo No. 3 Mine	Travertine
2	Takab Creme Choplo Mine	Marble and Travertine
3	Takab Choplo No. 2 Mine	Marble and Chocolate Travertine
4	Takab Bash Barat Mine	Chocolate Travertine

In order to construct a processing plant, three locations are proposed, that the location and characteristic of each one of them have been presented as follow.

Place A1:

Location: It is close to the Bash Barat mine and has less distance to the city of Takab.

Descriptions: This location has a better position in terms of topography and proximity to the city of Takab, but in some respects, for example access to underground water and unskilled manpower, is not at a good rank.


Takab Choplo No. 3 Mine


Takab creme Choplo Mine


Takab Choplo No. 2 Mine


Takab Bash Barat Mine

Fig. 1. Photographs of the studied mines.

Place A2:

Location: it is located in about 2 kilometers from the village of Choplo towards Shahindezh.

Descriptions: It has almost a same distance with mines and is also closer to the surrounding villages. This place has access to water supplies, it is closer to mines, but it is far from the consumption market.

Place A3:

Location: it is located in About 3 kilometers from the village of Choplo towards Shahindezh.

Figure 2 shows the studied mines and proposed locations of this study.

Descriptions: There is an acceptable distance between mines and this place and its access to route is also appropriate.

The effective criteria for choosing the most suitable place qualitatively have been presented in Table 2.

Fig. 2. Studied mines and proposed locations.

Table 2
Key factors affecting set up site selection.

Parameter Symbol	Parameter Qualitative description
C_1	Depth to access Underground Water Table
C_2	Distance to Access high voltage Electric Power Lines (Km)
C_3	Distance to Access Urban Gas Pipelines (Km)
C_4	Mean Mines access Distance (Km)
C_5	Distance to Nearest Market (Km)
C_6	Nearest Native Worker Living Place from Mines (Km)
C_7	Topography Condition of Site
C_8	Land Possessing cost ($)

3. Appropriate site selection of processing set up

The VIKOR method which is based on consensus planning of multi-criteria decision-making issues, evaluates issues with inappropriate and incompatible criteria. under the circumstances that the decision maker is unable to define superiorities of a case at the time of its beginning and design, VIKOR could be introduced as a powerful method for making decision. The steps in the VIKOR method are as follows [13].

3.1. Decision matrix forming

According to the criteria and alternatives the decision matrix is obtained as follows [13].

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Where x_{ij} is the function of the i-th alternative $(i = 1,2, \dots, m)$ in relation to the criterion j, $(j = 1,2, \dots, m)$. The decision matrix for the alternatives and criteria of the issue under study in this research can be formed as Table 3.

Table 3
Decision Matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.63	0.91	0.45	0.60	0.45	0.91	0.21	0.77
A_2	0.57	0.22	0.6	0.53	0.6	0.22	0.87	0.31
A_3	0.51	0.33	0.65	0.59	0.65	0.33	0.43	0.54

Based on the criteria inserted in table 2, all proposed alternatives were evaluated; the results of these investigations have been presented in Table 4.

Table 4
Qualitative Values of Decision Matrix.

	C_1 (Km)	C_2 (Km)	C_3 (Km)	C_4 (Km)	C_5 (Km)	C_6 (Km)	C_7 (Km)	C_8 ($)
A_1	0.63	0.91	0.45	0.60	0.45	0.91	1	100
A_2	0.57	0.22	0.6	0.53	0.6	0.22	4	40
A_3	0.51	0.33	0.65	0.59	0.65	0.33	2	70
Sum	6125	89.71	1841.44	115.09	1841.44	89.71	21	16500

As shown in Table 4, among the criteria under investigation, the C7 criterion is a qualitative criterion, which becomes quantitative according to Table 5.

Table 5
Qualitative Value to Quantitative Conversion.

Qualitative Description	Very Good	Good	Average	Bad	Very Bad
Rate	1	2	3	4	5

3.2. Decision matrix normalizing

At this stage, it is tried to convert the criteria with different dimensions into the criteria without dimension, so the matrix F is defined as follows. The non-scalable matrix has been shown in Table 6.

$$F = \begin{bmatrix} f_{11} & \cdots & f_{1n} \\ \vdots & \cdots & \vdots \\ f_{m1} & \cdots & f_{mn} \end{bmatrix} \quad (2)$$

Where in this matrix

$$f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \quad (3)$$

Table 6
Normalized Decision Matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.63	0.91	0.45	0.60	0.45	0.91	0.21	0.77
A_2	0.57	0.22	0.60	0.53	0.60	0.22	0.87	0.31
A_3	0.51	0.33	0.65	0.59	0.65	0.33	0.43	0.54

3.3. Criteria weight vector determination

At this step, considering the significance of different criteria in decision making, the vector is defined as follows, that table 6 shows the values obtained for each criterion (Table 7):

$$W = [w_1, w_2, \dots, w_n] \quad (4)$$

Table 7
Calculated Weight of Criteria.

C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
0.073	0.139	0.024	0.257	0.257	0.139	0.073	0.039

3.4. Calculate the best and worst value of each criteria

The best f_j^* and f_j^- for positive and negative criteria is calculated by the following equations, respectively:

$$f_j^* = Max(f_{ij})\ for\ positive\ f_j^* = Min(f_{ij})\ for\ negative \quad (5)$$

$$f_j^- = Min(f_{ij})\ for\ positive\ f_j^- = Max(f_{ij})\ for\ negative \quad (6)$$

In these equations, f_j^* is the best value of j criterion among all alternatives and f_j^- is the worst value of j criterion among all alternatives. In table 7, values f_j^* and f_j^- and in table 8, the value of difference f_j^- of f_j^* for each obtained criterion is shown in Table 8 and Table 9.

Table 8
Calculated criteria f_j^* and f_j^- value.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
f_j^*	0.51	0.22	0.45	0.53	0.45	0.22	0.87	0.31
f_j^-	0.63	0.91	0.60	0.60	0.60	0.91	0.21	0.77
$f_j^* - f_j^-$	0.12	0.69	0.19	0.07	0.19	0.69	0.65	0.46

Table 9
Differences of f_{ij} and f_j^*.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.13	0.69	0.00	0.07	0.00	0.69	0.65	0.47
A_2	0.06	0.00	0.15	0.00	0.15	0.00	0.00	0.00
A_3	0.00	0.11	0.20	0.06	0.20	0.11	0.44	0.23

3.5. Regret and utility values calculation

The values of S and R are obtained using following equations, that S and R values obtained for all three alternatives have been presented in Table 10 and Table 11 respectively [13]:

$$S_i = \sum_{j=1}^{n} W_j \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \tag{7}$$

Table 10
Calculated utility values of each alternative.

Places Utility	*Calculated Value*
S_1	0.7200
S_2	0.2476
S_3	0.6226

$$R_i = Max\left\{W_j \cdot \frac{f_j^* - f_{ij}}{f_j^* - f_j^-}\right\} \tag{8}$$

Where W_j is desired weight value for the j-th criterion.

Table 11
Calculated regret values of each alternative.

Alternatives Regret	*Calculated Value*
R_1	0.2570
R_2	0.1931
R_3	0.2570

In the adaptive planning method, if the parameter P is equal to one, the same value of S_i is obtained [13]:

$$L(A_i) = \sum_{j=1}^{n} W_j \cdot \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} = S_i \tag{9}$$

In the adaptive planning method, if the parameter P is equal to ∞, the same value of R_i is obtained [13]:

$$L_\infty(A_i) = Max\left\{W_j \cdot \frac{f_j^* - f_{ij}}{f_j^* - f_j^-}\right\} = R_i \tag{10}$$

3.6. VIKOR index (Q) calculation

The Q value is determined based on the following relation and with the help of the values of Table 12 and Table 13 for all three alternatives, and has been presented in Table 14:

$$S^* = Max(S_i) \tag{11}$$

$$R^* = Max(R_i) \tag{12}$$

$$Q_i = v\left[\frac{S_i - S^-}{S^* - S^-}\right] + (1 - v)\left[\frac{R_i - R^-}{R^* - R^-}\right] \tag{13}$$

Table 12
Calculated utility values of each alternative.

Places Utility	***Calculated Value***
S_j^*	0.7200
S_j^-	0.2476
$S_j^* - S_j^-$	0.4724

Table 13
Calculated regret values of each alternative.

Alternatives Regret	***Calculated Value***
R_j^*	0.2570
R_j^-	0.1931
$R_j^* - R_j^-$	0.0639

In these equations, $\frac{S_i - S^-}{S^* - S^-}$ indicate the distance rate from the ideal solution and $\frac{R_i - R^-}{R^* - R^-}$ indicate the distance rate from anti-ideal solution and the parameter v is selected according to the agreement ratio of the decision maker group. The value of Q is a function of S_i and R_i, that these values are the distance values from the ideal solution for $P = 1$ and $P = \infty$ in the consensus planning. Vikor Index values in Table 14 is obtained using $v = 0.5$.

Table 14
Calculated VIKOR Index (Q).

VIKOR Index	***Calculated Value***
Q_1	1.0000
Q_2	0.0000
Q_3	0.8969

3.7. Alternatives sorting due to R, S, Q values

In this stage, with regard to the Q, S, and R, the options are arranged in 3 groups, from smaller to larger, the ranking of options has been presented in Table 15. Finally, the option is chosen as the superior option, which will be recognized as the superior option in all three groups. It must be mentioned that in the Q group an option is selected as the best option using following 2 conditions:

Table 15
Alternatives Ranking.

Rank	***Calculated Parameters***					
1	Q_2	0/0000	S_2	0/2476	R_2	0/1390
2	Q_3	0/8969	S_3	0/6226	R_3	0/1931
3	Q_1	1/0000	S_1	0/7200	R_1	0/2570

Condition 1: If the options A_1 and A_2 are respectively the 1th and 2th best options in the group and n denotes the number of options, the following equation is made, that the results obtained by the help of this equation have been presented in Table 16:

$$Q(A_1) - Q(A_2) \geq \frac{1}{n-1} \tag{14}$$

Table 16
Condition No. 1 checking.

0.8969	≥	**0.5**

Condition 2: A_1 must be selected as the best rank in at least one of the S and R groups.

When the 1th condition isn't established, a set of options is nominated as the best options as follows:

$$\text{Alternatives priority} = A_1, A_2, A_3, \ldots, A_m$$

The maximum of m is considered according to the equation 15:

$$Q(A_m) - Q(A_1) < \frac{1}{n-1} \tag{15}$$

When the 2th condition is not established, the two options of A_1 and A_2 are selected as the superior options. The second condition also holds, because the Q_2 option has the highest rank in the R and S ranking list. With regard to the existence of two above conditions, the Q_2 option is suggested as the superior option.

4. Conclusion

Further development of stone industry in the country and the increase of stones variety in the market require the construction of qualified and accessible processing plants. Selecting the location of the construction of these processing units requires studies concerning the purchase of land, access routes and facilities for equipping and setting up the plant. In order to select the appropriate construction site, the options for constructing a processing plant should be investigated and compared according to these criteria. In this study, 3 sites located in west Azerbaijan were considered and 8 criteria such as transportation, water supply, electricity supply, gas supply, distance to markets, the price of land, topography and distance to where personal supplement place were analyzed. In order to select the appropriate place for the construction of a processing plant, in this research by VIKOR method firstly the decision matrix was formed, and then making non-scalable with the norm and determining the vector of weight criterion, the best and worst values among available values for each criterion, the usefulness value and the regret value for each option is calculated. Next, the Q value for each option was calculated and performed the ranking. The results obtained from this ranking suggest the second option as the best location. According to the obtained Q values (0.8969, 0.0000, 0.1000, respectively for A1, A2 and A3), case of A2 was selected as best choice.

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