RISK ASSESSMENT IN DECORATIVE AND FACADE STONE MINES UTILIZING COMPOSITE APPROACH OF FUZZY AHP AND FUZZY TOPSIS METHODS

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Abstract:

Mining decorative and facade stones is considered as a high-risk industry because of high volume of investment, and dealing with various technical and economic variables. Moreover, evaluating and rating of risks when productive risk factors are high is considered as one of the most important and meanwhile most complex risk management processes. Rating project risks is the key section of evaluation phase in risk management process. Therefore, identifying and prioritizing risks can have a significant role in success of a project. The main goal of this study is to present a model for identifying and rating risks due to its importance in decorative and facade stone mines. For this reason firstly, the risks are identified by the technique ofrisk breakdown structure. In next step, ten indexes are determined in order to assess the risks. The experts' ideas and comments have been collected by preparing Double Comparison Questionnaire of the indexes and a questionnaire for decision-making whichare based on risk breakdown structure. Finally, with utilizing composite Fuzzy Analytic Hierarchy ProcessandFuzzyTechnique for Order Preference by Similarity to Ideal Solutionas a composite

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approach with presenting a more realistic and robust results compared to other methods of decision making, risks have been rated. Fuzzy Analytic Hierarchy Processin determining weights of factors and final rating of risks utilizing these weights is done through prioritizing technique with FuzzyTechnique for Order Preference by Similarity to Ideal Solution. The results show that executive risks and natural disasters have got allocated the highest and lowest risks accordingly.

Keywords:
Decorative and facade stone mines, Risk Assessment, Risk Breakdown Structure (RBS), Multi-criteria evaluation decision, Fuzzy AHP, Fuzzy TOPSIS.

Introduction:

Developing countries for reaching economic growth have to increase their investment in infrastructure and mining industries. These sections in addition to provide basic needs bear a positive effect on speeding economic growth. Designing and operating decorative and facade stone mining projects implicates expending a huge amount of assets, and because of dealing with several economic and technical parameters is considered as one of the most venturesome projects. Identifying creative risk factors and knowing amount and type of their effects and accurate rating of them is the main step in correct assessment and on time response to these risks and lead to decreasing loss caused by these events.

Some of the done researches related to present study are: Oraee and Basiri in 2011, have evaluated and rated risks utilizing FUZZY TOPSSIS method in an underground mine which exploit with block caving method and showed that risk related to reserve assessment is in highest rate and also stated advantages of fuzzy methods compared to common methods in mining projects (Oraee & Basiri, 2011). David Hillson in 2006, for better understanding and more efficient management of project risk developed a work fracture structure and presented risk breakdown structure as the developing method of work fracture structure, as a more efficient approach (Hillson, 2002). Evans and Brereton in 2007 pointing that one of the limitations of traditional risk decreasing methods is that they mostly centralized on avoiding negative events, they have emphasized that form sustainable development point of facade we have to consider positive effects as well (Evans, Brereton & Joy, 2007). Oraee and Basiri in 2011 studied risk assessment through fuzzy technique of FMEA in mine tunnel excavating operation (Oraee & Basiri, 2011). Radosavljevića in 2009 studied risk assessment in mining and industries of Serbia during 2004-2008 period in exploiting ground surface in mining and industries of Serbia (Radosavljevića, 2009). Fuenteset alin 2009 has classified present risks in cooper mining industry in Chile and utilized Monte Carlo method in assessing risks (Fuentes, George & Whittikar, 2009).Mansour Momeni in 2012 with utilizing AHP fuzzy method and TOPSIS fuzzy has rated methods of technology choosing. They used fuzzy AHP method for determining weight of decision-making domain and fuzzy TOPSIS for rating technology (Momeni, 2012). Xiaobing Yu in 2010 with utilizing fuzzy AHP and fuzzy TOPSIS have evaluated and rated ecommerce websites. They showed efficiency and effectiveness of this method through a case study (Xiaobing Yu, 2010). Serkan Balli in 2009 using composite Fuzzy TOPSIS and Fuzzy AHP methods for choosing efficient operating system. They used FAHP method for showing weight of decision-making and rated operating systems with FTOPSIS method and mentioned efficiency of this composite method (Balli, 2009).

Objective of this study is to present an approach for identifying and rating of risks in decorative and facade stone mines. Rating is a multi-criteria decision-making issue. For this reason firstly, a comprehensive structure of primary risks in decorative and facade stone mines prepared with utilizing RBS tool and then various indexes for assessing risk factors has determined. And finally, Fuzzy AHP used to determine weights of factors and final rating of risks with the help of these weights will be done though prioritizing with Fuzzy TOPSIS. Presenting such method will compensate common rating methods and in-composite decision-making methods. Also, identifying risk creating factors and knowing rate and type of effects of risks from one hand and correct rating of them from other hand as section of complex process of risk management is a main step in correct assessing and appropriate and on time responding to these risks and results in reducing loss due to these events.

Risk Breakdown Stature in Decorative and Facade Stone Mines

Risk Breakdown Structure (RBS) is defined as "A source-oriented grouping of project risks that organizes and defines the total risk exposure of the project. Each descending level represents an increasingly detailed definition of sources of risk to the project (Hillson, 2002)."Instead of going through big spreadsheet with hundreds of verbose entries about risks, RBS provides – a pictorial representation of related items through tree structure as an excellent way of getting the whole picture in a single place for effective communication, management and governance.Organizations have common list of risk categories or even template with sample risks for each category and type of project. This can be used as starting point for risk identification. Though RBS has lot of advantages – here are few (Hillson, 2002):

* RBS give structured approach to risk identification through which all risk areas are explored without fail

* Grouping risks by common root causes can lead to developing effective risk responses

* RBS helps in risk assessment by interviewing or meetings with participants selected for their familiarity with a specific risk category

* RBS give greater ability monitor and control risks identified classified under the same area or root

Risk breakdown structure in decorative and façade stone mines has been designed and prepared in form of three levels. In this risk breakdown structure first level divided into two groups of risks due to external sources and risks due to internal sources, level two divided into ten sublevels and level three divided into 76 sublevels. In this paper, researcher tries to rank level two risks only.

Table 1:Risk Breakdown Stature in Decorative and Facade Stone Mines

Level 0	Level 1	Level 2	Level 3
Project Risk	Project risks arising from external sources	Market	Termination of contract
			Customer's inability to pay debts
			Lack of on time supply of equipment and machinery, consumer services
			Rising cost of equipment and facilities
			Rising transportation costs
			Fluctuations in mineral material prices
		Natural disasters	Unpredicted forecast and ground conditions
			Earthquake
			Floodwater
			Flood
			Hurricane
			Fires
		Macroeconomic	instability of government's economic policies
			Taxes and customs duties increasing
			Price volatility

			Economic sanctions on the government
			Changes in stock prices
			Changes in interest rates
			Changes in exchange rates
			Increase in inflation
			Rising energy prices
		Political	Political events occurrence (revolutions, coups, etc.)
			Pressure of beneficial groups
			Changes in operating policy of authorities who design election regulation
			External threats (war and sanctions)
			Administrative corruption
			Possibility of Nationalization of mines
			Changing expectations of government
			Changes in domestic and foreign policies.
			Political instability of region
			Political instability of government
		Legal	Changes in insurance condition
			Changes of regulation in favor of a beneficial company
			Legal disputes
			Changes in capital adequacy
			Environmental standards and environmental requirements
			Confirmation of regulatory and Permission
			mistakes and ambiguities in the contract
		Eco-environmental	Improper design of failed dam
			Changes in eco-environmental regulations and policies
			Noise pollution Creation
			Air pollution creation
			Health pollution (water and soil)
	Project risks arising from internal sources	Technical	Design
			Geotechnical
			Environmental conditions and the mine site (Topographical condition, roads access, mine security, etc.)
			Shipping damage and overturning of machineries (trailers) while loading from dam
			Geology (uncertainty estimation of reserves, the hydrology and water influx, etc.)
			Boreholing
			Electrocution due to worn out cables

			Maintenance of equipment and machinery
			Micro stones falling alongnatural discontinuities and damage of persons and machinery.
			Damage caused by blasting open new face
			Cope unexpected release of Stone in direction of layering
			Diamond cutting wire cut
		Management	Mismatch of expertise and experience of managers with their position
			Lack of project management methods and techniques
			Relations of parties involved in the project management level
			Improper distribution of funds, human resource and equipment
			Lack of cost and time control during design and implementation
			Lack of strategic project planning
			Poor control of mines
		Executive	Employer
			Subcontractor
			Commitments and guarantees
			The main contractor
			Human resources
			Consultant
			Suppliers of equipment and machinery
		Investment & Financial	Unrealistic cost estimation
			Flow in cost plan
			Forecast cash flows and non-compliance with capital inventory
			Financial and budget bankruptcy
			Lack of on time financial resources

Analytic Hierarchy Process (AHP)

The AHP pioneered in 1971 by Saaty (Saaty, 2008)is a widespread decision-making analysis tool for modeling unstructured problems in areas such as political, economic, social, and management sciences (Mohmoodzadeh et al., 2007). The AHP method is based on three principles: first, structure of the model; second, comparative judgment of the alternatives and the criteria; third, synthesis of the priorities (Mohmoodzadeh et al., 2007).

Fuzzy Set Theory

To deal with vagueness of human thought, Zadeh (Zadeh, 1965) first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing indistinct data. The theory also allows mathematical operators and programming to apply into the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. A tilde "~" will be placed above a symbol if the symbol represents a fuzzy set (Mohmoodzadeh et al., 2007).

A triangular fuzzy number (TFN) M is shown in Fig. 2. A TFN is denoted simply as (l, m, u). The parameters l, m and u, respectively, denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event (Xiaoguang, 2012)

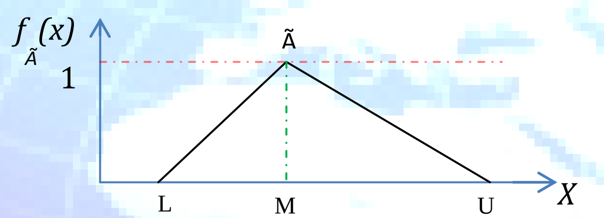


Figure1: Display a Triangular Fuzzy Number

Fuzzy AHP Method

Though the purpose of AHP is to capture the expert's knowledge, the conventional AHP still cannot reflect the human thinking style. Therefore, Fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems (Kahraman, Cebci& Ulukan, 2003). In the Fuzzy-AHP procedure, the pair wise comparisons in the judgment matrix are fuzzy numbers that are modified by the designer's emphasis (Kahraman, Cebci& Ulukan, 2003). According to the method of Chang's (Chang, 1992), extent analysis, each object is taken and extent analysis for each goal is performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs(Mohmoodzadeh et al., 2007):

$M^1gi, M^1gi, \ldots, M^mgi \qquad i=1,2,\ldots,n \qquad (1)$

Step 1: The value of fuzzy synthetic extent with respect to the i[th] object is defined as:

$$S_k = \sum_{j=1}^{n} M_{kl} \times \left[\sum_{i=1}^{m}\sum_{j=1}^{n} M_{ij}\right]^{-1} \qquad (2)$$

Step2:As $M_1=(l_1, m_1, u_1)$ and $M_2=(l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2=(l_2,m_2,u_2) \geq M_1=(l_1,m_1,u_1)$ is defined as:

$$\begin{cases} V(M_1 \geq M_2) = 1, & M_1 \geq M_2 \\ V(M_1 \geq M_2) = 0, & M_1 \leq M_2 \\ V(M_1 \geq M_2) = hgt(M_1 \geq M_2), & else \end{cases} \qquad (3)$$

That:

$$hgt(M_1 \geq M_2) = \frac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)} \qquad (4)$$

Step3:Calculating the possibility degree for a convex fuzzy number

$$w'^{(x_i)} = \min\{V(S_i \geq S_k\}, k = 1,2, \ldots n \qquad k \neq i \qquad (5)$$

$$w' = [w'(c_1), w'(c_2), \ldots, w'(c_n)]^T \qquad (6)$$

Step4:Via normalization, the normalized weight vectors are:

Where W is a non-fuzzy number.

$$w_i = \frac{w'(c_i)}{\sum_{i=1}^{K} w'(c_i)} \qquad (7)$$

$$W = [w_1, w_2, w_3 \ldots\ldots w_n] \qquad (8)$$

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The general TOPSIS processes with six activities are listed below (Olson, 2004):

-Establishing a decision matrix for ranking.

-Calculating the normalized decision matrix.

-Measuring the weighted normalized decision matrix.

- Determination of the positive-ideal solution (PIS) and negative-ideal solution (NIS) (ChiSun, 2010).

- Calculating the separation measures.

- Calculate the relative closeness to the idea solution and ranking the alternatives in descending order.

Stage 1:Establishing a decision matrix for ranking: The structure of the matrix can be expressed as follows:

$$D = \begin{array}{c} \\ A1 \\ A2 \\ \vdots \\ An \end{array} \begin{array}{c} \begin{array}{cccc} F1 & F2 & \ldots & Fn \end{array} \\ \begin{bmatrix} f11 & f12 \ldots. & & f1n \\ f21 & f22 \ldots. & & f2n \\ \vdots & \vdots & & \vdots \\ fm1 & fm2 & \ldots & fmn \end{bmatrix} \end{array} \qquad (9)$$

(D is a decision matrix)

Where A_i denotes the alternatives i, i = 1, … ,m. F_j represents j^{th} attribute or criterion, j = 1,…, n, calculate the separation measures, using the m dimensional related to i^{th} alternative.

Stage 2:The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sum_j^n f_{ij}^2} \qquad (10)$$

Where j = 1. . . n; i = 1, . . . ,m.

Stage 3:Measuring the weighted normalized decision matrix by multiplying the normalized decisions by its associated weights. The weighted normalized value V_{ij} is calculated as:

$$\check{v}_{ij} = \check{r}_{ij}(\cdot)\breve{w}_{ij} \qquad (11)$$

Where w_j represents the weight of the j^{th} criterion.

Stage 4:Determination of the PIS and NIS respectively:

$$V^+ = \{V_1^+, \ldots, V_n^+\} = \{(MaxV_{ij} | j \in J), (MinV_{ij} | j \in J')\} \qquad (12)$$

$$V^- = \{V_1^-, \ldots, V_n^-\} = \{(MinV_{ij} | j \in J'), (MaxV_{ij} | j \in J)\} \quad (13)$$

Where J is associated with the positive criteria and J' is associated with the Negative criteria.

Stage 5:Calculating the separation measures by using the m dimensional Euclidean distance. The separation measure d_i of each alternative from the PIS is given as:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^+)^2} \quad (14)$$

Similarly, the separation measure of each alternative from the NIS is as follows:

$$d_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2} \quad (15)$$

Stage 6:Calculate the relative closeness to the idea solution and ranking the alternatives in descending order. The relative closeness of the alternative A_i with respect to PIS, V^+, can be expressed as:

$$CL_i^* = \frac{d_i^-}{d_i^- + d_i^+} \quad (16)$$

Where the index value of CL_i^* lies between 0 and 1.

Fuzzy TOPSIS Method

The method is based on the concept that the chosen alternative should have the shortest distance from the positive-ideal solution. The longest distance from the negative-ideal solution TOPSIS defines an index called similarity to the positive-ideal solution and the remoteness from the negative-ideal solution. Then, the method chooses an alternative with the maximum similarity to the positive-ideal solution (Hwang & Yoon, 1981).

The mathematics concept of the Fuzzy TOPSIS is reviewed briefly as follows:

Step 1: Forming decision-makers committee:

In this committee there are K decision-makers. Decision makers can be represented by a linguistic term.

$$\tilde{x}_{ij} = \frac{1}{k}[\tilde{x}_{ij}^1 (+) \tilde{x}_{ij}^2 (+) \cdots (+) \tilde{x}_{ij}^k] \,, \quad (17)$$

Step2: Evaluation of the criteria:

The criteria are evaluated as in table 2:

Table2: Linguistic scales

Very Poor(VP)	Poor(P)	Medium Poor(M)	Fair(F)	Medium Good(MG)	Good(G)	Very Good(VG)
(0,0,2)	(1,2,3)	(2,3.5,5)	(4,5,6)	(5,6.5,8)	(7,8,9)	(8,10,10)

Step 3: Normalizing the fuzzy-decision matrix:

The normalized fuzzy-decision matrix is measured as the following formula:

$$\tilde{R} = [\check{r}_{ij}]_{m\times n} \quad ,i = 1, \dots, m\ ,j = 1, \dots, n \qquad (18)$$

The normalization process can be performed by the following formula:

$$\tilde{r}_{ij} = (\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}),\ c_j^* = \max_i c_{ij} \quad ,if\ j \in c \qquad (19)$$

$$\tilde{r}_{ij} = (\frac{c_j^-}{c_{ij}}, \frac{c_j^-}{b_{ij}}, \frac{c_j^-}{a_{ij}}),\ a_j^- = \min_i a_{ij} \quad ,if\ j \in b \qquad (20)$$

B: Profit criteria set; C: Loss criteria set

Step 4: Determining the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS):

$$\check{v} = [\check{v}_{ij}]_{m\times n}, \quad i = 1, \dots, m \quad ,j = 1, \dots, n \qquad (21)$$

$$\check{v}_{ij} = \check{r}_{ij}(\cdot)\check{w}_{ij} \qquad (22)$$

According to the weighted normalized fuzzy-decision matrix, the elements $\check{v}_{ij}$ are normalized positive and their ranges belong to the closed interval [0,1]. Then, the FPIS A^+ (the aspiration levels) and FNIS A^- (the worst levels) are defined as the following formula (Hwang & Yoon, 1981):

$$A^+ = (\check{v}_1^*, \check{v}_2^*, \dots, \check{v}_n^*) \qquad (23)$$

$$A^- = (\check{v}_1^-, \check{v}_2^-, \dots, \check{v}_n^-)$$

Step 5: Calculating the distance of each alternative from FPIS and FNIS:

The distances of each alternative from A^+ andA^- can be calculated by the area compensation method, as follows:

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*) \ , \quad i = 1, \dots, m \ , \tag{24}$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \ , \quad i = 1, \dots, m \ , \tag{25}$$

Step6: Obtaining the closeness coefficients (relative gaps-degree) and improving the alternatives for achieving aspiration levels in each criterion.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \qquad A_i (i = 1, \dots, m) \tag{26}$$

Risk Assessment in Decorative and Facade Stone Mines

Rating risks in decorative and facade stone mines includes four main steps as below:

Step1: Identifying risks in decorative and facade stone mines utilizing risk breakdown structure

Step2: Determining evaluation risk factors

Step3: Preparing questionnaire for double comparison of factors and adaptive questionnaire and gathering experts' ideas (in this study numbers of experts are 10 people)

Step4: Determining weights of factors with fuzzy hierarchical analysis method

Step 5: Rating risks utilizing analyzing similarity to ideal fuzzy solution

Step One: Identifying and defining possible risks in decorative and facade stone mines resulted form risk breakdown structure, which are described in first part of this paper. In this study, secondary level risks of fracture structure in decorative and facade stone mines, which includes 10 sublevels, will be rate.

Step Two:Define and determine risk assessment factors. For overcoming limitation of number of factors in classic method of risk assessment of risk management process, moreover to PMBOK guide who includes possibility of occurrence and rate of effectiveness of risk on objectives of project (time, cost, quality, operation), five other complementary factors suggested. 10 assessment factors for risks of problem considered.

1- "Manageability" states ability of organization in predicting risk occurrence and ability of manage and respond to that.

2- “Continuity frequency” states frequency and number of time facing this risk in project.
3- “Rate of discovery” shows capacity of discovery and rate of being familiar to this risk by risk assessment managers
4- “Proximity of occurrence” states proximity of occurrence of risk in project
5- “Level of Trust” shows rate of analyzer trust to results of estimation of risk assessment values
6- “Possibility of Occurrence” shows expectation of estimator from occurrence of risk event
7- “Effect on Time” states rate of risk effectiveness on project time
8- “Effect on Cost” states rate of risk effectiveness on project cost
9- “Effect on Quality” states rate of effectiveness of risk on health, quality, and accuracy of project
10- “Effect on Functionality” Shows the effectiveness of risk on operation and function of project

Step three:Based on step one (risk breakdown structure) and step two (determining risk assessment factors), questionnaireof double comparison of factors and decision making questionnaire are designed and prepared and experts opinions will be collect.

Step four:Determine the criteria weights with fuzzy AHP method

1) Calculating the Inconsistency Ratio

Table 3: Tables of Inconsistency Ratio of double comparison matrix completed by experts

λ_{max1}	10.947
II_1	0.105
IRI_1	1.51
IR_1	0.07

λ_{max2}	10.276
II_2	0.031
IRI_2	1.51
IR_2	0.02

λ_{max3}	11.27
II_3	0.141
IRI_3	1.51
IR_3	0.093

λ_{max4}	10.826
II_4	0.092
IRI_4	1.51
IR_4	0.061

λ_{max5}	11.192
II_5	0.132
IRI_5	1.51
IR_5	0.088

λ_{max6}	10.491
II_6	0.055
IRI_6	1.51
IR_6	0.036

λ_{max7}	10.272
II_7	0.03
IRI_7	1.51
IR_7	0.02

λ_{max8}	11.313
II_8	0.146
IRI_8	1.51
IR_8	0.097

λ_{max9}	10.5
II_9	0.056

λ_{max10}	11
II_{10}	11

IRI_9	1.51
IR_9	0.037

IRI_{10}	1.51
IR_{10}	0.07

Inconsistency ratio of these matrixes which are lower than 0.1 and hence their consistency is acceptable.

2) Determining double comparison of indexes

Table 4: Valuation fuzzy matrix of double comparison of indexes

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	1 1 1	0.18 0.88 3.5	0.50 2.07 4.00	0.20 1.35 5.50	4.00 5.11 8.00	2.00 4.09 8.00	0.33 4.59 7.50	0.19 0.69 2.00	0.33 5.32 9.00	0.25 2.33 5.75
C_2	0.29 2.53 5.50	1 1 1	2.00 3.57 6.00	0.40 2.34 3.50	3.00 6.04 8.00	2.00 4.97 7.00	3.50 5.47 8.50	0.33 0.75 2.00	4.00 6.28 9.00	1.00 3.10 5.00
C_3	0.25 0.79 2.00	0.17 0.35 0.50	1 1 1	0.18 0.85 3.00	3.00 4.25 7.00	0.50 2.77 6.50	0.33 3.78 6.00	0.17 0.34 0.80	0.33 4.44 7.00	0.25 1.64 4.50
C_4	0.18 1.73 5.00	0.29 0.80 2.50	0.33 2.49 5.50	1 1 1	3.75 5.49 7.00	3.00 4.34 5.50	2.00 4.67 7.00	0.20 0.42 0.75	2.63 5.51 8.00	0.50 2.36 3.50
C_5	0.13 0.21 0.25	0.13 0.19 0.33	0.14 0.25 0.33	0.14 0.19 0.27	1 1 1	0.25 0.70 2.00	0.20 1.16 4.00	0.13 0.15 0.21	0.20 1.73 4.00	0.17 0.57 2.00
C_6	0.13 0.29 0.50	0.14 0.24 0.50	0.15 0.72 2.00	0.18 0.24 0.33	0.50 2.25 4.00	1 1 1	0.25 2.14 6.00	0.13 0.18 0.27	0.33 2.48 5.00	0.22 0.46 1.00
C_7	0.13 0.49 3.00	0.12 0.20 0.29	0.17 0.53 3.00	0.14 0.26 0.50	0.25 2.20 5.00	0.17 1.45 4.00	1 1 1	0.11 0.16 0.22	0.14 1.76 5.00	0.13 0.37 0.67
C_8	0.50 2.65 5.25	0.50 1.81 3.00	1.25 3.85 5.75	1.33 2.93 5.00	5.50 7.00 8.00	3.75 5.87 8.00	4.50 6.34 9.00	1 1 1	3.5 6.56 8.50	0.25 3.53 5.50
C_9	0.11 0.47 3.00	0.11 0.17 0.25	0.14 0.49 3.00	0.13 0.2 0.38	0.25 1.49 5.00	0.20 0.94 3.00	0.20 1.49 7.00	0.12 0.16 0.29	1 1 1	0.13 0.27 0.50
C_{10}	0.17 1.10 4.00	0.20 0.43 1.00	0.31 1.79 4.00	0.04 0.58 2.00	0.50 3.94 6.00	1.00 2.92 4.00	1.50 3.45 8.00	0.18 0.27 0.36	2.00 4.40 8.00	1 1 1

Note:
C_1: Possibility of Occurrence, C_2: Manageability, C_3: Continuity frequency, C_4: Rate of discovery, C_5: Proximity of occurrence, C_6: Level of Trust, C_7: Effect on Time, C_8: Effect on Cost, C_9: Effect on Quality, C_{10}: Effect on Functionality

3) Calculating the S value

S_1 = (8.99, 27.43, 54.25) ×(0.0027, 0.0049, 0.0117) = (0.0241, 0.1337, 0.6321)

S_2 = (17.52, 36.06, 55.50) × (0.0027, 0.0049, 0.0117) = (0.0471, 0.1757, 0.6467)

S_3 =(6.19, 20.21, 38.30) × (0.0027, 0.0049, 0.0117) = (0.0166, 0.0985, 0.4463)

S_4 =(13.88, 28.81, 45.75) × (0.0027, 0.0049, 0.0117) = (0.0373, 0.1404, 0.5331)

S_5 = (2.48, 6.15, 14.39) × (0.0027, 0.0049, 0.0117) = (0.0067, 0.0300, 0.1677)

S_6 =(3.03, 10.00, 20.60) × (0.0027, 0.0049, 0.0117) = (0.0082, 0.0487, 0.2400)

S_7 =(2.36, 8.43, 22.67) ×(0.0027, 0.0049, 0.0117) = (0.0063, 0.0411, 0.2642)

S_8 =(22.08, 41.55, 59.00) ×(0.0027, 0.0049, 0.0117) = (0.0593, 0.2025, 0.6875)

S_9 =(2.38, 6.70, 23.42) ×(0.0027, 0.0049, 0.0117) = (0.0064, 0.0326, 0.2728)

S_{10} = (6.91, 19.86, 38.36) ×(0.0027, 0.0049, 0.0117) = (0.0186, 0.0968, 0.4470)

4)Measuring the degree of possibility

$$V(S_1 \geq S_2) = \frac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)} = \frac{0.6321 - 0.0471}{(0.6321 - 0.0471) + (0.1757 - 0.1337)} = 0.9330$$

$V(S_1 \geq S_3)$ =1, $V(S_1 \geq S_4)$ =0.9888, $V(S_1 \geq S_5)$ =1, $V(S_1 \geq S_6)$ =1,$V(S_1 \geq S_7)$ =1

$V(S_1 \geq S_8)$ =0.8928, $V(S_1 \geq S_9)$ =1, $V(S_1 \geq S_{10})$ =1

$V(S_2 \geq S_1)$ =1, $V(S_2 \geq S_3)$ =1, $V(S_2 \geq S_4)$ =1, $V(S_2 \geq S_5)$ =1, $V(S_2 \geq S_6)$ =1,

$V(S_2 \geq S_7)$ =1, $V(S_2 \geq S_8)$ =0.9564, $V(S_2 \geq S_9)$ =1, $V(S_2 \geq S_{10})$ =1

$V(S_3 \geq S_1)$ =0.9231, $V(S_3 \geq S_2)$ =0.8379, $V(S_3 \geq S_4)$ =0.9070, $V(S_3 \geq S_5)$ =1,

$V(S_3 \geq S_6)$ =1, $V(S_3 \geq S_7)$ =1, $V(S_3 \geq S_8)$ =0.7882, $V(S_3 \geq S_9)$ =1, $V(S_3 \geq S_{10})$ =1

$V(S_4 \geq S_1)$ =1, $V(S_4 \geq S_2)$ =0.9323, $V(S_4 \geq S_3)$ =1, $V(S_4 \geq S_5)$ =1, $V(S_4 \geq S_6)$ =1

$V(S_4 \geq S_7)$ =1, $V(S_4 \geq S_8)$ =0.8842, $V(S_4 \geq S_9)$ =1, $V(S_4 \geq S_{10})$ =1

$V(S_5 \geq S_1)$ =0.5806, $V(S_5 \geq S_2)$ =0.4529, $V(S_5 \geq S_3)$ =0.6880, $V(S_5 \geq S_4)$ =0.5415

$V(S_5 \geq S_6)$ =0.8948, $V(S_5 \geq S_7)$ =0.9357, $V(S_5 \geq S_8)$ =0.3859, $V(S_5 \geq S_9)$ =0.9838

$V(S_5 \geq S_{10})$ =0.6906

$V(S_6 \geq S_1)$ =0.7177, $V(S_6 \geq S_2)$ =0.6031, $V(S_6 \geq S_3)$ =0.8179, $V(S_6 \geq S_4)$ =0.6886

$V(S_6 \geq S_5)$ =1, $V(S_6 \geq S_7)$ =1, $V(S_6 \geq S_8)$ =0.5403, $V(S_6 \geq S_9)$ =1,$V(S_6 \geq S_{10})$ =0.8217

$V(S_7 \geq S_1)$ =0.7216, $V(S_7 \geq S_2)$ =0.6173, $V(S_7 \geq S_3)$ =0.8117, $V(S_7 \geq S_4)$ =0.6955

$V(S_7 \geq S_5)$ =1, $V(S_7 \geq S_6)$ =0.9709, $V(S_7 \geq S_8)$ =0.5593, $V(S_7 \geq S_9)$ =1

$V(S_7 \geq S_{10})$ =0.8151

$V(S_8 \geq S_1)$ =1, $V(S_8 \geq S_2)$ =1, $V(S_8 \geq S_3)$ =1, $V(S_8 \geq S_4)$ =1, $V(S_8 \geq S_5)$ =1

$V(S_8 \geq S_6)$ =1, $V(S_8 \geq S_7)$ =1, $V(S_8 \geq S_9)$ =1, $V(S_8 \geq S_{10})$ =1

$V(S_9 \geq S_1)$ =0.7111, $V(S_9 \geq S_2)$ =0.6121, $V(S_9 \geq S_3)$ =0.7955, $V(S_9 \geq S_4)$ =0.6861

$V(S_9 \geq S_5)$ =1, $V(S_9 \geq S_6)$ =0.9427, $V(S_9 \geq S_7)$ =0.9694, $V(S_9 \geq S_8)$ =0.5570

$V(S_9 \geq S_{10})$ =0.7985

$V(S_{10} \geq S_1)$ =0.9198, $V(S_{10} \geq S_2)$ =0.8352, $V(S_{10} \geq S_3)$ =0.9961, $V(S_{10} \geq S_4)$ =0.9038,

$V(S_{10} \geq S_5)$ =1, $V(S_{10} \geq S_6)$ =1, $V(S_{10} \geq S_7)$ =1, $V(S_{10} \geq S_8)$ =0.7858, $V(S_{10} \geq S_9)$ =1

5) Calculating the possibility degree for a convex fuzzy number

$$V(S_1 \geq S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}) = Min(0.9330,1,0.9888,1,1,1,0.8928,1,1) = 0.8928$$

$$V(S_2 \geq S_1, S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}) = Min(1,1,1,1,1,1,1,0.9564,1,1) = 0.9564$$

$$V(S_3 \geq S_1, S_2, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}) = Min(0.9231,0.8379,0.9070,1,1,1,0.7882,1,1) = 0.7882$$

$$V(S_4 \geq S_1, S_2, S_3, S_5, S_6, S_7, S_8, S_9, S_{10}) = Min(1,0.9323,1,1,1,1,0.8842,1,1) = 0.8842$$

$$V(S_5 \geq S_1, S_2, S_3, S_4, S_6, S_7, S_8, S_9, S_{10}) = Min(0.5806,0.4529,0.6880,0.5415,0.8948,0.9357,0.3859,0.9838,0.6906) = 0.3859$$

$$V(S_6 \geq S_1, S_2, S_3, S_4, S_5, S_7, S_8, S_9, S_{10}) = Min(0.717,0.603,0.8179,0.6886,1,1,0.5403,1,0.8217) = 0.5403$$

$$V(S_7 \geq S_1, S_2, S_3, S_4, S_5, S_6, S_8, S_9, S_{10}) = Min(0.721,0.617,0.811,0.695,1,0.970,0.559,1,0.815) = 0.559$$

$$V(S_8 \geq S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_9, S_{10}) = Min(1,1,1,1,1,1,1,1,1,1) = 1$$

$$V(S_9 \geq S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_{10}) = Min(0.7111,0.6121,0.7955,0.6861,1,0.9427,0.9694,0.5570,0.7985) = 0.5570$$

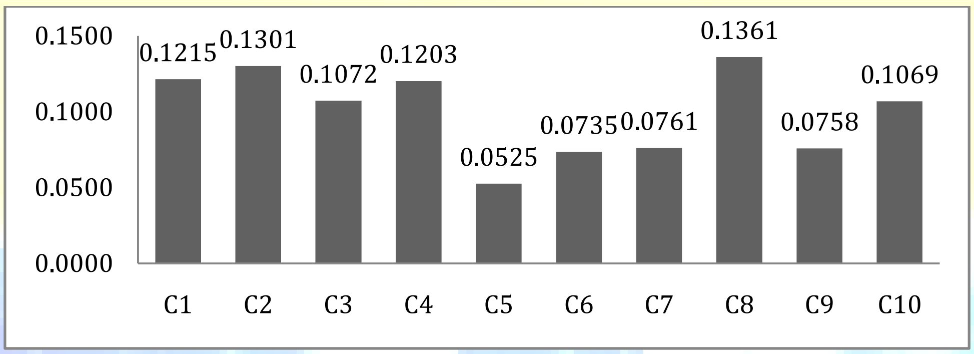
$$V(S_{10} \geq S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9) = Min(0.9198,0.8352,0.9961,0.9038,1,1,1,0.7858,1) = 0.7858$$

$W' = (0.8928, 0.9564, 0.7882, 0.8842, 0.3859, 0.5403, 0.5593, 1, 0.5570, 0.7858)^T$

6) Normalized values of criteria weights

W=(0.1215,0.1301,0.1072,0.1203,0.0525,0.0735,0.0761,0.1361,0.0758,0.1069)

Diagram 1: Display normalized values of criteria weights FUZZY AHP method



Step Five: The Risks Ranking with Fuzzy TOPSIS Method

1) Determining the Fuzzy decision matrix

Table 5: Fuzzy decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
R_1	2 4.5 7	1 1.55 3	2 4.33 6	3 5.88 8.5	5 7.3 9	2 5 9	4 6.13 8	2 3.4 9	2 2.7 3	2 4 5
R_2	6.5 8.3 9	3 4.7 6	2 6 8	2 4.73 6.5	6 7.85 9	7 8.6 9	6 7.85 9	8 8.4 9	4 5.3 8	4 5.65 7
R_3	2 7.08 9	1 3.45 5	4 7.6 9	1 4.63 7	3 5 7	3 5.18 8	8 8.65 9	3 4.33 6.3	4.5 5.38 6.3	4 6.85 8.5
R_4	1.25 3.12 5	4 5.93 7	3 3.83 5	4 6.45 9	2 3.25 4	2 3.17 4.7	3 5 8	3 4.15 6	2 3.65 7	3 3.7 5
R_5	1 1.15 2	1 2.25 3	1 1.83 4.8	1 3.15 8	1 1.5 2.5	1 3.18 7	1 5.58 9	1 1.57 2.5	1 1.32 2	1 1.3 3
R_6	4 5.93 8	7 8.6 9	3 4.6 7	4 5.27 6	1 3.6 5	4 5.73 8	4 4.75 5	5 6.63 7	4.5 6.63 8	7 8 9

R_7	4 5.1 8	5 6.83 9	4.5 5.7 7	3 5.66 8.5	1 3.65 6	2 3.8 5	6 6.96 8.6	5 6.23 7	6 7.35 9	6 7.35 9
R_8	4 6.4 8	6.8 7.43 8	5 7.58 9	3 6.1 9	5 6.7 9	2 4.13 5	2 5.18 7	8 8.75 9	8 8.8 9	7 8.35 9
R_9	1 4 7.5	4 5.41 8	1 2.15 3	2 5.75 9	1 2.2 3	1 4.05 6	1 2.45 4	1 1.7 3	1 1.32 2	1 1.82 3
R_{10}	3 5.1 7	6 6.75 8	2.5 4.65 6	4 6 8	4 6.35 9	5 6.4 8	5 7 8	5 6.4 8	4 5.75 6.5	4 5.65 7

Note:

R_1: Political Risk, R_2: Macroeconomic Risk, R_3: Market Risk, R_4: Legal Risk, R_5: Natural disasters Risk, R_6: Technical Risk, R_7: Management Risk, R_8: Executive Risk, R_9: Environmental Risk, R_{10}: Investment & Financial Risk

2) Determining the Normal Matrix

Table 6: The normal fuzzy matrices

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
R_1	0.22 0.50 0.78	0.33 0.64 1.00	0.22 0.48 0.67	0.12 0.17 0.33	0.56 0.81 1.00	0.11 0.20 0.50	0.44 0.68 0.89	0.22 0.38 1.00	0.22 0.30 0.33	0.22 0.44 0.56
R_2	0.72 0.94 1.00	0.17 0.21 0.33	0.22 0.67 0.89	0.15 0.21 0.5	0.67 0.87 1.00	0.11 0.12 0.14	0.67 0.87 1.00	0.89 0.94 1.00	0.44 0.59 0.89	0.44 0.63 0.78
R_3	0.22 0.79 1.00	0.20 0.29 1.00	0.44 0.85 1.00	0.14 0.22 1.00	0.33 0.56 0.78	0.13 0.20 0.33	0.89 0.96 1.00	0.33 0.48 0.70	0.50 0.60 0.70	0.44 0.76 0.94
R_4	0.14 0.35 0.56	0.14 0.17 0.25	0.33 0.43 0.56	0.11 0.16 0.25	0.22 0.36 0.44	0.21 0.32 0.5	0.33 0.56 0.89	0.33 0.46 0.67	0.22 0.40 0.78	0.33 0.41 0.56
R_5	0.11 0.13 0.22	0.33 0.44 1.00	0.11 0.20 0.53	0.13 0.32 1.00	0.11 0.17 0.28	0.14 0.32 1.00	0.11 0.62 1.00	0.11 0.17 0.28	0.11 0.15 0.22	0.11 0.14 0.33
R_6	0.44 0.66 0.89	0.11 0.12 0.14	0.33 0.51 0.78	0.17 0.19 0.25	0.11 0.40 0.56	0.13 0.17 0.25	0.44 0.52 0.56	0.56 0.73 0.78	0.50 0.73 0.89	0.78 0.89 1.00
R_7	0.44 0.57 0.89	0.11 0.15 0.20	0.50 0.63 0.78	0.12 0.18 0.33	0.11 0.40 0.67	0.20 0.26 0.5	0.67 0.77 0.96	0.56 0.70 0.78	0.67 0.82 1.00	0.67 0.82 1.00

R_8	0.44 0.71 0.89	0.13 0.14 0.15	0.56 0.84 1.00	0.11 0.16 0.33	0.56 0.75 1.00	0.20 0.24 0.50	0.22 0.57 0.78	0.89 0.98 1.00	0.89 0.98 1.00	0.78 0.93 1.00
R_9	0.11 0.44 0.83	0.13 0.18 0.25	0.11 0.24 0.33	0.11 0.17 0.5	0.11 0.24 0.33	0.17 0.25 1.00	0.11 0.27 0.44	0.11 0.19 0.33	0.11 0.15 0.22	0.11 0.21 0.33
R_{10}	0.33 0.57 0.78	0.13 0.15 0.17	0.28 0.52 0.67	0.13 0.17 0.25	0.44 0.71 1.00	0.13 0.16 0.20	0.56 0.78 0.89	0.56 0.71 0.89	0.44 0.64 0.72	0.44 0.63 0.78

4) Determining the FPIS and FNIS

$$V_j^+ = \begin{bmatrix} (0.088,0.112,0.121), (0.014,0.015,0.019), (0.060,0.091,0.107), (0.013,0.019,0.030), \\ (0.035,0.046,0.053), (0.008,0.009,0.011), (0.068,0.073,0.076), (0.121,0.132,0.136), \\ (0.067,0.074,0.076), (0.083,0.099,0.107) \end{bmatrix}$$

$$V_j^- = \begin{bmatrix} (0.013,0.016,0.027), (0.043,0.084,0.130), (0.012,0.022,0.036), (0.020,0.038,0.120), \\ (0.006,0.009,0.015), (0.016,0.023,0.074), (0.008,0.021,0.034), (0.015,0.024,0.038), \\ (0.008,0.011,0.017), (0.012,0.015,0.036) \end{bmatrix}$$

5) Calculating the distance of each Risks from FPIS and FNIS:

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
FPIS	0.3858	0.1298	0.299	0.3446	0.6194	0.185	0.1768	0.0903	0.501	0.1996
FNIS	0.3008	0.5326	0.405	0.3228	0.0621	0.4786	0.4863	0.567	0.1692	0.4615

6) The closeness coefficients are:

Risks	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
Cc	0.44	0.80	0.58	0.48	0.09	0.72	0.73	0.86	0.25	0.70
Rank	8	2	6	7	10	4	3	1	9	5

As Cci amount is greater, it will be more critical risks.

Conclusion:

Applying risk management strategies in decorative and façade mines is an unavoidable fact because of high amount of investment and dealing with various technical and economic parameters. Lack of proper decision making is dealing with identification, classification, and selection, and wherever we are facing unstable situation, we have to make decision. One of those regions which needs decision making is project management. Risk management is one of the project management phases and risk assessment is one of the main steps in risk management. Risk assessment means calculating risks based on predetermined factors, and ranking these risks make possible the methods of fighting these risks in next levels of risk management. The aim of this paper is to present a model for identifying and ranking these risks from the importance in decorative and façade stones mines point of view. That's why, a comprehensive structure of risks in decorative and façade stone mines in three levels were prepared by utilizing risk breakdown structure. In this research, level two of RBS which includes ten sublevel of political risk, economic risk, market risk, legal risk, natural disasters risks, technical risk, managerial risk, executive risks, eco-environmental risks, and financial and investment risks during the next steps are ranked. In next step, in addition to effective factors on objectives of the project based on project management standards, five more other factors for assessment of the risk factors determined. The experts' ideas were collected by preparing Double Comparison of sources questionnaire and decision making questionnaire based on risk breakdown structure. Eventually, the risk has been assessed and ranked by utilizing composite Fuzzy AHP and Fuzzy TOPSIS. For determining weight of factors, Fuzzy AHP and for finally ranking of risks utilizing these weights done based in Fuzzy TOPSIS. As a result, based on presented model risks of decorative and façade stone mines ranked and factors due to executive risks and natural disasters has the highest and lowest risk respectively and also executive, economic (macro), managerial are identified the highest risks in decorative and façade stone mines.

Further, ranking risks in decorative and façade stone mines with composite approach of Fuzzy AHP and Fuzzy TOPSIS which are considered as a principal objective of this research, the following important results are also drawn:

- Utilizing FUZZY Multi Attribute Decision Making compared to classic method of risk assessment (effect-possibility matrix), with a special focus on more factors which give more reliable results.
- For taking benefits of composite approach advantages and present an approach with high reliability value, present research compose common methods of decision making that weakness points of each one will compensate with strengths points of the others to present a solution for ranking decorative and façade stone mines. Presented approach is based on Fuzzy AHP and Fuzzy TOPSIS, this approach is usable in all cases of decision making and compensate weakness of common methods of decision making.

- Risk breakdown structure prepares possibility of determining project risks in a vast level and is a framework for other identification techniques such as Brain storming.

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