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Ranking of Factors Affecting the Critical Path Using Fuzzy Multi Criteria Decision Making Method

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Abstract: Critical path evaluation and selection is a key element in the project control process and appears to be one of the major activities of the professional project management. The aim of this study is develop a model with high reliability for ranking of factors affecting the critical path. In this study, to identify the factors affecting the implementation of critical path was used the Delphi method and used fuzzy preference programming and fuzzy Delphi, fuzzy AHP and SIR. VIKOR for ranking of factors affecting the critical path. We construct a questionnaire for fuzzy AHP and SIR. VIKOR and to increase the validity of Cronbach's alpha index is used. The results indicate that the four indicators cost, service, delivery and quality are the most important factors affecting the critical path.

Key words: Critical path, fuzzy logic, fuzzy Delphi, fuzzy AHP, SIR.VIKOR

INTRODUCTION

Selection of the appropriate critical path is a major requirement for an effective project management. According to Lachmayer and Afsari (2012), critical path evaluation and selection is a key element in the project control process and appears to be one of the major activities of the professional project management. Individual firms no longer compete as autonomous entities but rather by joining a project management alliance. Members in the project management always forge stronger alliances to compete against other project management (Wang *et al*., 2009). Experts believe that critical path is one of the most prominent activities of project management (Wang, 2004). Selection of the best critical path is a difficult problem for managers because the performances of critical paths are varied based on each criterion (Lootsma, 2001). Selection of the best critical path in project is a Group Decision-Making (GDM), cross functional problem with long-term commitment for firms (Lachmayer and Afsari, 2013). Selection of the best critical path problem deals with defining potential critical paths, selecting the best set of critical paths among them and determining the shipment quantity of each (Wang *et al*., 2009).

In selection of the best critical path problem it is very important to choose scientific and rational evaluation criteria which are the first step to conduct evaluation (Shemshadi *et al*., 2011).

In real life, the modeling of many conditions may not be sufficient as the available data are inexact, vague and uncertain nature. The aim of this study is develop a model with most affecting factors on critical path. In this study, we use fuzzy Delphi, fuzzy AHP and SIR.VIKOR as a decision tool to ranking of factors affecting the critical path. According Fuzzy Delphi Method, the key indicators can be derived. Then for the determination of the relative importance of selection criteria, FAHP can be used since it is based on pairwise comparisons allows the utilization of linguistic variables. Based on the AHP approach to pairwise comparison is the most demanding in terms of solicited input by opinion of experts. We used SIR.VIKOR for the first time for ranking of factors affecting the critical path problem. The SIR.VIKOR method utilizes superiority (S-matrix) and inferiority (I-matrix) matrix and VIKOR methods. Rebai (1994) suggested SIR method is based on the theory of fuzzy bags. By VIKOR method was introduced by Opricovic and Tzeng (2004) as a multi criteria decision making method to solve a discrete DM problem with non-commensurable and conflicting criteria. According to their study this method focuses on ranking and selecting from a set of alternatives. In this study, we used SIR.VIKOR technique for the first time in project management problem. The aim of this study is develop a model with high reliability for ranking of factors affecting the critical path. From fuzzy Delphi we identified nine essential criteria and with FAHP we calculated weight these criteria and with SIR.VIKOR we choose the best critical path.

MATERIALS AND METHODS

In this study, we use hybrid model as a fuzzy Delphi, fuzzy AHP and SIR.VIKOR for ranking of most affecting factors on critical path. Firstly we used fuzzy Delphi method to extract critical criteria in critical path. Linguistic variables are used for importance weights of various criteria and the ratings of qualitative criteria. To identify the factors affecting the implementation of critical path was used the Delphi method and used fuzzy preference programming and fuzzy Delphi, fuzzy AHP and SIR.VIKOR for ranking of factors affecting the critical path.

Fuzzy delphi: Murry *et al.* (1985) proposed the concept of integrating the traditional Delphi method and fuzzy Delphi Method to improve the vagueness data. Membership degree is used to establish the membership function of each participant. Ishikawa *et al.* (1993) further introduced fuzzy integration algorithms to predict the prevalence of computers and the fuzzy theory into the Delphi Method. In this study, we used traditional Delphi technique and Fuzzy Delphi Method was proposed by Ishikawa *et al.* (1993). In this study we use twelve experts to extract the critical criteria of oil Company. The Fuzzy Delphi Method (FDM) steps are as follows (Chang and Hung, 2010):

- Collect opinions of decision group: by each expert by using linguistic variables in questionnaires we find the evaluation score of each alternate factor's significance given
- Set up triangular fuzzy numbers: determination the evaluation value of triangular fuzzy number of each criteria factor by experts and in this study used the geometric mean model by Klir and Yuan (1995) for fuzzy Delphi Method to find out the common understanding of group decision

The computing formula is illustrated as follows. Assuming the evaluation value of the significance of No.J element given by No.i expert of n experts is $\tilde{W}_{ij}=(a_{ij},b_{ij},c_{ij})$, i = 1, 2, ..., n, j = 1, 2, ..., m. Then, the fuzzy weighting $\tilde{w}$ of No. j Element is $\tilde{W}_{ij}=(a_{ij},b_{ij},c_{ij})$. Among which:

$$a_j=\min\{a_{ij}\},\ b_j=\frac{1}{n}\sum_{i=1}^{n}b_{ij},\ c_j=\max\{c_{ij}\} \tag{1}$$

Defuzzification: Use gravity method to defuzzify the fuzzy weight $\tilde{W}_{ij}$ of each alternate element to definite value S_j, the followings are obtained:

$$S_j=\frac{a_j+4b_j+c_j}{6} \tag{2}$$

Table 1: Linguistic variables for importance of each criterion

Variables	Criterion
Absolutely appropriate	(9,10,10)
Appropriate	(7,9,10)
Slightly appropriate	(5,7,9)
Neutral	(3,5,7)
Slightly inappropriate	(1,3,5)
Inappropriate	(0,1,3)
Absolutely inappropriate	(0,0,1)

Table 2: Linguistic variables for weight of each criterion

Variables	Criterion
Extremely strong	(9,9,9)
Intermediate	(7,8,9)
Very strong	(6,7,8)
Intermediate	(5,6,7)
Strong	(4,5,6)
Intermediate	(3,4,5)
Moderately strong	(2,3,4)
Intermediate	(1,2,3)
Equally strong	(1,1,1)

Screen evaluation indexes: Finally, proper factors can be determined from numerous criteria by setting the threshold α as follows (Table 1):

- If $S_j \geq \alpha$: then No. j factor is the evaluation index
- If $S_j < \alpha$: then delete No. j factor

The selection criteria were:

- If MA≥r: 0.8, this appraisal indicator is accepted
- If MA<r: 0.8, this appraisal indicator is rejected

Fuzzy Analytic Hierarchy Process (FAHP): Laarhoven and Pedrycz proposed the Fuzzy Analytic Hierarchy Process in 1983 which was an application of hybrid model of the fuzzy theory and Analytic Hierarchy Process (AHP).

When a decision maker is making a decision the linguistic scale of traditional AHP method could express the fuzzy uncertainty (Table 2). The steps of research method based on FAHP are as follows (Shen and Yu, 2009):

- Determine decision making matrix with expert' opinion
- Set up hierarchy architecture: this study determined the important criteria conforming to target problems through fuzzy Delphi method based on experts' opinions to set up the hierarchy architecture
- To the pairwise comparisons according AHP Method we assign linguistic terms as following matrix $\tilde{A}$:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{21} & \dots & \tilde{a}_{21} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{21} \\ \tilde{a}_{21} & \tilde{a}_{21} & \dots & 1 \end{bmatrix} = \begin{pmatrix} 1 & \tilde{a}_{21} & \dots & \tilde{a}_{21} \\ \frac{1}{\tilde{a}_{21}} & 1 & \dots & \tilde{a}_{21} \\ \frac{1}{\tilde{a}_{21}} & \frac{1}{\tilde{a}_{21}} & \dots & 1 \end{pmatrix} \quad (3)$$

Where:

$$\tilde{a}_{ij} = \begin{cases} \tilde{9}^{-1}, \tilde{8}^{-1}, \tilde{7}^{-1}, \tilde{6}^{-1}, \tilde{5}^{-1}, \tilde{4}^{-1}, \tilde{3}^{-1}, \tilde{2}^{-1}, \tilde{1}^{-1}, \tilde{1}, \tilde{2}, \tilde{3}, \tilde{4}, \tilde{5}, \tilde{6}, \tilde{7}, \tilde{8}, \tilde{9} & i \neq j \\ 1 & i = j \end{cases}$$

Chamodrakas *et al*. (2010) introduced geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each criterion:

$$\tilde{r}_i = \left(\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes, \dots, \otimes \tilde{a}_{in}\right) \quad (4)$$

$$\tilde{w}_i = \tilde{r}_i \otimes \left(\tilde{r}_1 \oplus \tilde{r}_2 \oplus, \dots, \oplus \tilde{r}_n\right)^{-1} \quad (5)$$

a_{ij} is dimension i to criterion j fuzzy comparison value, thus $\tilde{r}_i$ is a criterion i to each criterion's geometric mean of fuzzy comparison value, $\tilde{w}_i$ is the fuzzy weight of the ith criterion $\tilde{w}_i = (lw_i, mw_i, uw_i)$. The lw_i, mw_i and uw_i, stand for the lower, middle and upper values of the fuzzy weight of the dimension.

SIR.VIKOR

Step 1: According to SIR Method $g_1, g_2, \dots, g_n$ are the criteria and $A_1, A_2, \dots, A_n$ are the alternatives and $g_j(A_1)$ is alternative with respect to criteria's value (Table 3).

$$D = \begin{pmatrix} g_1(A_1) & g_2(A_1) & \dots & g_n(A_1) \\ g_1(A_2) & g_2(A_2) & \dots & g_n(A_2) \\ g_1(A_m) & g_2(A_m) & \dots & g_n(A_m) \end{pmatrix} \quad (6)$$

In this study, for defuzzification used graded mean integration approach. According to the graded mean integration approach, for triangular fuzzy numbers, a fuzzy $\tilde{C} = (C_1, C_2, C_3)$ number can be transformed into a crisp number by employing the below equation (Sanayei *et al*., 2010):

$$P(\tilde{C}) = \tilde{C} = \frac{c_1 + 4c_2 + c_3}{6} \quad (7)$$

Step 2: According to six generalized criteria types and SIR method for each alternative A_i, the superiority index $S_j(A_i)$ and inferiority index $I_j(A_i)$ with respect to the criterion are calculated as Eq. 8 and 9:

Table 3: Linguistic variables for importance of each alternative

Variables	Abbrevations	Alternatives
Absolutely appropriate	AAP	(9,10,10)
Appropriate	AP	(7,9,10)
Slightly appropriate	SAP	(5,7,9)
Neutral	N	(3,5,7)
Slightly inappropriate	SINAP	(1,3,5)
Inappropriate	INAP	(0,1,3)
Absolutely inappropriate	AINAP	(0,0,1)

$$S_j(A_i) = \sum_{k=1}^{m} P(A_i, A_k) = \sum_{k=1}^{m} f_j(g_j(A_i) - g_j(A_k)) \quad (8)$$

$$I_j(A_i) = \sum_{k=1}^{m} P(A_k, A_i) = \sum_{k=1}^{m} f_j(g_j(A_k) - g_j(A_i)) \quad (9)$$

Generalized criteria: Type 1: true criterion:

$$f(d) = \begin{cases} 1 & \text{if} \quad d \geq 0 \\ 0 & \text{if} \quad d < 0 \end{cases} \quad (10)$$

Type 2: quasi criterion:

$$f(d) = \begin{cases} 1 & \text{if} \quad d \geq q \\ 0 & \text{if} \quad d < q \end{cases} \quad (11)$$

Type 3: criterion with linear preference:

$$f(d) = \begin{cases} 1 & \text{if} \quad d \geq p \\ \frac{d}{p} & \text{if} \quad 0 < d \leq p \\ 0 & \text{if} \quad d \leq 0 \end{cases} \quad (12)$$

Type 4: level criterion:

$$f(d) = \begin{cases} 1 & \text{if} \quad d \geq p \\ \frac{1}{2} & \text{if} \quad q < d \leq p \\ 0 & \text{if} \quad d \leq q \end{cases} \quad (13)$$

Type 5: criterion with linear preference and indifference area:

$$f(d) = \begin{cases} 1 & \text{if} \quad d \geq p \\ \frac{d-q}{p-q} & \text{if} \quad q < d \leq p \\ 0 & \text{if} \quad d \leq q \end{cases} \quad (14)$$

Type 6: gaussian criterion:

$$f(d) = \begin{cases} 1 & \text{if} \quad d \geq 0 \\ 0 & \text{if} \quad d < 0 \end{cases} \quad (15)$$

Then, determined the superiority (S-matrix) and inferiority (I-matrix) indexes: the superiority matrix (SI-matrix):

$$S = \begin{pmatrix} S_1(A_1) & S_2(A_1) & \dots & S_n(A_1) \\ S_1(A_2) & S_2(A_2) & \dots & S_n(A_2) \\ S_1(A_m) & S_2(A_m) & \dots & S_n(A_m) \end{pmatrix} \quad (16)$$

The inferiority matrix (QI-matrix):

$$I = \begin{pmatrix} I_1(A_1) & I_2(A_1) & \dots & I_n(A_1) \\ I_1(A_2) & I_2(A_2) & \dots & I_n(A_2) \\ I_1(A_m) & I_2(A_m) & \dots & I_n(A_m) \end{pmatrix} \quad (17)$$

Step 3: Calculated the worst value (WV, f_j^-) and best value of (BV, f_j^*) all criteria functions for each matrix as following equations. For S-matrix:

$$S_j^+ = (\max_i S_1(A_i),\dots,\max_i (S_n(A_i)) = (S_1^+,\dots,S_n^+) \quad (18)$$

$$S_j^- = (\min_i S_1(A_i),\dots,\min_i S_n(A_i)) = (S_1^-,\dots,S_n^-) \quad (19)$$

$$SS_j = \sum_{j=1}^{n} \frac{w_j(S_j^+ - S_j(A_i))}{(S_j^+ - S_j^-)} \quad (20)$$

$$RS_j = \max_j \left[\frac{w_j(S_j^+ - S_j(A_i))}{(S_j^+ - S_j^-)} \right] \quad (21)$$

For I-matrix:

$$I_j^+ = (\min_i I_1(A_i),\dots,\min_i (I_n(A_i)) = (I_1^+,\dots,I_n^+) \quad (22)$$

$$I_j^- = (\max_i I_1(A_i),\dots,\max_i I_n(A_i)) = (I_1^-,\dots,I_n^-) \quad (23)$$

$$SI_j = \sum_{j=1}^{n} \frac{w_j(I_j^+ - I_j(A_i))}{(I_j^+ - I_j^-)} \quad (24)$$

$$RI_j = \max_j \left[\frac{w_j(I_j^+ - I_j(A_i))}{(I_j^+ - I_j^-)} \right] \quad (25)$$

Step 4: Calculated S^*, S^-, R^*, R^-, values for each matrix:
For S-matrix:

$$S\,S^* = \min_i S_i;\ S\,S^- = \max_i S_i;\ R\,S^* = \min_i R_i;\ R\,S^- = \max_i R_i$$

For I matrix:

$$S\,I^* = \min_i S_i;\ S\,I^- = \max_i S_i;\ R\,I^* = \min_i R_i;\ R\,I^- = \max_i S_i$$

Step 5: Calculating Q_i value for each alternatives and ranking based on for each matrix as equations (Deng and Chan, 2011). For S-matrix:

$$QS_i = v\left[\frac{SS_i - SS^*}{SS^- - SS^*}\right] + (1-v)\left[\frac{RS_i - RS^*}{RS^- - RS^*}\right] \quad (26)$$

For I-matrix:

$$QI_i = v\left[\frac{SI_i - SI^*}{SI^- - SI^*}\right] + (1-v)\left[\frac{RI_i - RI^*}{RI^- - RI^*}\right] \quad (27)$$

According to VIKOR Method, minimum of Q_i for each matrix is the best alternative.

Case study: Our proposed methodology is applied to oil company in Iran is a conglomeration of a parent enterprise and its 33 subsidiaries engaged in development and implementation of railway transportation and other industrial projects under EPC and IP schemes, power, oil and gas as well as manufacturing relative equipment.

Oil company has ventured into projects to generate over 7000 MW of electricity corresponding to a total contract value of more than €2.5 billion as an investor and main contractor of independent power and industrial projects.

RESULTS AND DISCUSSION

Evaluating model application:

Stage one: First a Fuzzy Delphi Method interview table is setup and second interview was done with 12 experts from oil Company. Nine criteria were identified (Table 4).

Table 4: List of criteria and definition

Criteria	Definition
C_1: Quality	To provide a high-quality product, Critical path should have a quality system including quality assurance, quality improvement, quality control, quality control charts, documentation , etc
C_2: Cost	Cost of critical path is a high percentage of in total cost of project. Therefore project department wants to minimum price to decrease the total cost
C_3: Service	Project's service is a indicator for selection of the best critical path problem. This criteria contains after sale service and the quality in providing support services, such as purchasing, technology support, etc
C_4: Duration	Period of time which formed in critical path
C_5: Technology	Technical abilities represent that project management ability ensures future improvements according to changing in customer's needs
C_6: Response to	The time that critical path react to order or complain customer of customer
C_7: Past	The performance of project manager in past years in performance industry (for example for 10 years)
C_8: Flexibility	Ability to react to changes in requirements different project
C_9: Facility	Project management's facilities should meet critical path's specific requirements

Table 5: Fuzzy comparison matrix for the relative importance of criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	(1,1,1)	(1.718,2.595, 3.489)	(1.571,2.301, 3.25)	(2.097,3.157, 4.186)	(5.23,6.25, 7.23)	(3.616,4.708, 5.753)	(3.933,5.037, 6.058)	(3.707,4.748, 5.775)	(5.95,6.854, 7.726)
C2	(0.287,0.385, 0.582)	(1,1,1)	(0.643,0.855, 1.128)	(0.939,1.357, 1.819)	(3.41,4.521, 5.58)	(2.021,2.957, 3.814)	(2.354,3.28, 4.13)	(1.669,2.428, 3.322)	(3.996,5.059, 6.098)
C3	(0.331,0.434, 0.636)	(0.887,1.17, 1.554)	(1,1,1)	(1.026,1.4, 1.878)	(3.41,4.324, 5.164)	(2.153,3.004, 3.846)	(2.468,3.133, 3.916)	(1.969,2.823, 3.712)	(3.971,4.796, 5.592)
C4	(0.239,0.317, 0.477)	(0.55,0.737, 1.065)	(0.532,0.714, 0.971)	(1,1,1)	(2.725,3.565, 4.461)	(1.655,2.329, 3.028)	(1.723,2.504, 3.51)	(1.763,2.208, 2.601)	(3.616,4.663, 5.692)
C5	(0.138,0.16, 0.191)	(0.179,0.221, 0.293)	(0.194,0.231, 0.293)	(0.224,0.28, 0.367)	(1,1,1)	(0.372,0.455, 0.592)	(0.574,0.761, 1.02)	(0.412,0.526, 0.678)	(0.989,1.413, 1.969)
C6	(0.174,0.212, 0.276)	(0.262,0.338, 0.495)	(0.26,0.333, 0.464)	(0.33,0.429, 0.604)	(1.69,2.2, 2.692)	(1,1,1)	(1.04,1.313, 1.646)	(0.697,0.905, 1.188)	(2.174,3.058, 3.891)
C7	(0.165,0.198, 0.254)	(0.242,0.305, 0.425)	(0.255,0.319, 0.405)	(0.285,0.399, 0.58)	(0.98,1.313, 1.743)	(0.608,0.761, 0.964)	(1,1,1)	(0.452,0.627, 0.891)	(1.53,2.197, 2.944)
C8	(0.173,0.211, 0.27)	(0.301,0.412, 0.599)	(0.269,0.354, 0.508)	(0.385,0.453, 0.567)	(1.475,1.9, 2.428)	(0.841,1.105, 1.435)	(1.122,1.595, 2.21)	(1,1,1)	(2.255,2.927, 3.632)
C9	(0.129,0.146, 0.168)	(0.164,0.198, 0.25)	(0.179,0.209, 0.252)	(0.176,0.214, 0.276)	(0.508,0.707, 1.011)	(0.257,0.327, 0.46)	(0.327,0.434, 0.613)	(0.324,0.395, 0.503)	(1,1,1)

Table 6: The weights and rank of criteria

Rank	Fuzzy weight	Crisp weight	$\tilde{W}_i$
1	(0.187,0.302,0.487)	0.314	$\tilde{W}_1$
2	(0.094,0.156,0.226)	0.165	$\tilde{W}_2$
3	(0.08,0.165,0.276)	0.169	$\tilde{W}_3$
4	(0.078,0.126,0.217)	0.127	$\tilde{W}_4$
7	(0.02,0.037,0.063)	0.039	$\tilde{W}_5$
9	(0.04.0.064,0.11)	0.018	$\tilde{W}_6$
6	(0.032,0.051,0.089)	0.055	$\tilde{W}_7$
5	(0.043,0.068,0.117)	0.075	$\tilde{W}_8$
8	(0.019,0.028,0.048)	0.030	$\tilde{W}_9$

Stage two: The weights of evaluation criteria. Following the fuzzy AHP Model, we adopt fuzzy AHP method for the performance of technology selection criteria to evaluate the weights of different criteria.

According to the committee with twelve representatives about the relative important of criteria, then the pairwise comparison matrices of criteria will be obtained. We used fuzzy numbers defined in Table 2. We transfer the linguistic scales based on Buckley (1985) to computing the elements of synthetic pairwise comparison matrix by using the geometric mean method is:

$$\tilde{a}_{ij} = \left(\tilde{a}_{ij}^{1} \otimes \tilde{a}_{ij}^{2} \otimes .... \otimes \tilde{a}_{ij}^{11}\right)^{\frac{1}{11}} \quad (28)$$

It can be obtained the other matrix elements by the same computational procedure, therefore, the synthetic pairwise comparison matrices of the twelve representatives will be constructed as follows matrix A in Table 5. To calculate the fuzzy weights of criteria as following parts:

$$\tilde{r}_1 = \left(\tilde{a}_{11} \otimes \tilde{a}_{12} \otimes .\tilde{a}_{13} \otimes \tilde{a}_{14} \otimes \tilde{a}_{15} \otimes \tilde{a}_{16} \otimes \tilde{a}_{18} \otimes \tilde{a}_{19}\right)^{\frac{1}{9}}$$

$$\tilde{r}_1 = \left(2.76,3.556,4.294\right) \; \tilde{r}_2 = \left(1.385,1.839,2.343\right)$$

$$\tilde{r}_3 = \left(1.175,1.941,2.434\right) \; \tilde{r}_4 = \left(1.148,1.488,1.915\right)$$

$$\tilde{r}_5 = \left(0.357,0.438,0.553\right) \; \tilde{r}_6 = \left(0.602,0.757,0.973\right)$$

$$\tilde{r}_7 = \left(0.473,0.603,0.784\right) \; \tilde{r}_8 = \left(0.635,0.801,1.03\right) \quad (29)$$

$$\tilde{r}_9 = \left(0.276,0.333,0.421\right)$$

For the weight of each criterion, they can be done as follows:

$$\tilde{w}_i = \tilde{r}_i \otimes \left(\tilde{r}_1 \oplus \tilde{r}_2 \oplus .\tilde{r}_3 \oplus \cdot\tilde{r}_4 \oplus \tilde{r}_5 \oplus \tilde{r}_6 \oplus \tilde{r}_7 \oplus \tilde{r}_8 \oplus \tilde{r}_9\right)^{-1}$$

$$\tilde{w}_1 = \tilde{r}_1 \otimes \left(\tilde{r}_1 \oplus \tilde{r}_2 \oplus .\tilde{r}_3 \oplus \cdot\tilde{r}_4 \oplus \tilde{r}_5 \oplus \tilde{r}_6 \oplus \tilde{r}_7 \oplus \tilde{r}_8 \oplus \tilde{r}_9\right)^{-1} \quad (30)$$

Stage three: Evaluating the critical paths. committee of decision makers has been formed to select the most suitable critical path according to linguistic variable in Table 6. The crisp values for decision matrix is computed as shown in Table 7 and 8.

According to SIR.VIKOR Method we first construct the decision matrix. The numbers in this matrix with respect to each criterion are the value of each alternative.

Then we calculate the superiority (S-matrix) and inferiority (I-matrix) indexes of each alternative with respect to each criterion based on preferred generalized criterion type (Table 4) to construct superiority (S-matrix) and inferiority (I-matrix) indexes matrixes.

Table 7: Crisp values for decision matrix and weight of each criterion

	Criteria								
Alternative	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	7.61	7.00	8.22	8.22	9.17	7.61	7.61	8.22	9.50
A_2	8.22	7.61	8.22	8.56	8.56	7.61	8.22	6.33	7.61
A_3	8.22	8.22	8.22	7.61	7.61	7.00	7.61	6.33	8.83
A_4	8.22	7.61	6.33	7.00	8.56	7.61	7.61	7.11	8.22
A_5	8.22	7.61	7.61	6.33	7.94	8.83	7.61	6.33	7.28
A_6	8.22	7.61	7.61	8.56	7.00	8.56	7.56	8.22	7.61
A_7	7.61	5.67	7.61	6.33	7.61	6.95	4.33	5.00	8.22
A_8	6.33	7.56	8.83	6.95	6.33	8.22	7.00	7.89	8.22
A_9	9.17	3.73	7.61	8.83	8.56	7.61	6.95	6.33	8.56
A_{10}	8.22	6.33	7.00	7.61	7.61	7.61	6.33	6.33	7.00
A_{11}	7.61	2.39	5.00	4.33	7.61	7.94	7.00	6.95	8.22
A_{12}	7.61	7.00	6.33	3.73	5.67	7.00	5.00	6.33	5.67
A_{13}	7.63	5.28	7.23	3.15	6.01	6.87	5.13	6.46	5.61

Table 8: S-matrix (S)

	Criteria								
Alternative	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.278891	0.784244	1.294928	1.263118	2.569593	0.285898	1.071530	2.744696	2.832379
A_2	0.796031	1.064369	1.294928	1.552480	1.448334	0.285898	1.785201	0.163617	0.343474
A_3	0.796031	1.470385	1.294928	0.848328	0.463059	0.000637	1.071530	0.163617	1.490271
A_4	0.796031	1.064369	0.132502	0.554336	1.448334	0.285898	1.071530	0.722366	0.738268
A_5	0.796031	1.064369	0.697719	0.334989	0.702987	3.610732	1.071530	0.163617	0.224229
A_6	0.796031	1.064369	0.697719	1.552480	0.189256	2.556582	1.029888	2.744696	0.343474
A_7	0.278891	0.368591	0.697719	0.334989	0.463059	0.000000	0.000000	0.000000	0.738268
A_8	0.000000	1.038459	2.257193	0.535004	0.038982	1.439987	0.650699	2.022393	0.738268
A_9	3.327775	0.050313	0.697719	1.816001	1.448334	0.285898	0.624849	0.163617	1.099867
A_{10}	0.796031	0.549077	0.345744	0.848328	0.463059	0.285898	0.350401	0.000000	0.153645
A_{11}	0.278891	0.000000	0.000000	0.012265	0.463059	0.760846	0.650699	0.547414	0.738268
A_{12}	0.278891	0.784244	0.132502	0.000000	0.000000	0.000637	0.029962	0.163617	0.000000
A_{13}	0.281121	0.613422	0.152710	0.000000	0.070000	0.000319	0.031998	0.181721	0.000000

Table 9: I-matrix (I)

	Criteria								
Alternative	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.814113	0.093426	0.000000	0.020585	0.000000	0.638741	0.024901	0.000000	0.000000
A_2	0.164818	0.010641	0.029458	0.002496	0.033396	0.638741	0.000000	0.921379	0.636472
A_3	0.164818	0.000000	0.278977	0.123350	0.446333	2.005207	0.024901	0.921379	0.041450
A_4	0.164818	0.010641	1.672237	0.343639	0.033396	0.638741	0.024901	0.293636	0.188489
A_5	0.164818	0.010641	0.201101	0.759193	0.232431	0.000000	0.024901	0.921379	1.057858
A_6	0.164818	0.010641	0.201101	0.002496	1.158061	0.018399	0.029765	0.000000	0.636472
A_7	0.814113	0.789931	0.201101	0.759193	0.446333	2.161163	4.624436	3.530851	0.188489
A_8	4.974160	0.012733	0.000000	0.367687	2.422220	0.119453	0.216574	0.021879	0.188489
A_9	0.000000	2.997697	0.201101	0.000000	0.033396	0.638741	0.245130	0.921379	0.086802
A_{10}	0.164818	0.349850	0.691951	0.123350	0.446333	0.638741	0.818428	0.921379	1.521382
A_{11}	0.814113	4.923163	4.614400	3.121913	0.446333	0.295777	0.216574	0.388633	0.188489
A_{12}	0.814113	0.093426	1.672237	4.028415	3.999825	2.005207	3.157308	0.921379	4.706017
A_{13}	0.837821	0.061011	1.698153	3.992148	4.023412	1.997459	3.129810	0.961498	4.931567

Table 10: (BV, F^*_J) and worst value (WV, F^-_J) for S-matrix (S)

Criteria B and W values	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
f^*	3.327775	1.470385	2.257193	1.816001	2.569593	3.610732	1.785201	2.744696	2.832379
f^-	0	0	0	0	0	0	0	0	0
W	0.314	0.164	0.169	0.127	0.039	0.018	0.054	0.074	0.03

The S matrix and I matrix are as Table 9 and 10 respectably. The best value (BV, f_j^*) and worst value (WV, f_j^-) of all criteria functions for each matrix is determined as Table 11 and 12, respectably.

Then we calculated the values of SS, RS and QS for S-matrix (Table 10). The values of SI, RI and QI are determined with the same procedure as Table 13. Based on descending flow the best rank for alternative is consideration of SS and RS for S rank (the concepts of VIKOR Method) (Table 14). With the same procedure I rank is calculated as see in Table 15.

Table 11: (BV, F^*_J) and worst value (WV, F^-_J) for I-matrix (I)

Criteria B and W values	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
f^*	0	0	0	0	0	0	0	0	0
f^-	4.97416	4.923163	4.6144	4.028415	3.999825	2.161163	4.624436	3.530851	4.706017
W	0.314	0.164	0.169	0.127	0.039	0.018	0.054	0.074	0.03

Table 12: The values of SS, RS and QS

Critical path	SS	RS	QS
A_1	0.513088	0.287685	0.50068
A_2	0.504193	0.238889	0.334568
A_3	0.533969	0.238889	0.365782
A_4	0.663371	0.238889	0.501434
A_5	0.651639	0.238889	0.489135
A_6	0.509955	0.238889	0.340609
A_7	0.831059	0.287685	0.834008
A_8	0.576962	0.314	0.652193
A_9	0.43178	0.158388	0
A_4	0.746754	0.238889	0.588844
A_{10}	0.908745	0.287685	0.915445
A_{11}	0.859972	0.287685	0.864317
A_{12}	0.873452	0.288134	0.871151

Table 13: The values of SI, RI

Critical path	SI	RI	QI
A_1	0.060764	0.051392	0.094807
A_2	0.04093	0.01931	0.020601
A_3	0.065429	0.01931	0.046806
A_4	0.096129	0.061245	0.148909
A_5	0.070669	0.023934	0.060049
A_6	0.034053	0.011292	0
A_7	0.260559	0.074	0.345857
A_8	0.354818	0.314	0.843099
A_9	0.135596	0.099859	0.254905
A_4	0.099527	0.025342	0.093242
A_{10}	0.501504	0.169	0.760496
A_{11}	0.384629	0.127	0.566108
A_{12}	0.391289	0.134	0.581409

Table 14: I rank for I-matrix

SS	RS	QS	S rank
A_9	A_9	A_9	A_9
A_2	A_2	A_2	A_2
A_6	A_6	A_6	A_6
A_1	A_3	A_3	A_3
A_3	A_5	A_5	A_5
A_8	A_4	A_1	A_1
A_{10}	A_1	A_8	A_8
A_7	A_{12}	A_7	A_7

Table 15: I rank for I-matrix

SI	RI	QI	I rank
A_6	A_6	A_6	A_6
A_2	A_2	A_2	A_2
A_1	A_3	A_3	A_3
A_3	A_5	A_5	A_5
A_5	A_{10}	A_{10}	A_{10}
A_4	A_1	A_1	A_1
A_{10}	A_4	A_4	A_4

Now we compared results of S rank and I rank (Table 16). The results of comparing (S-rank and I-rank) shows that critical paths 2 and 6 are the best critical paths and critical paths 8, 7, 12 and 11 are the worst critical paths.

Table 16: Final S and I rank

SI	QI
A_9	A_6
A_2	A_2
A_6	A_3
A_3	A_5
A_5	A_{10}
A_1	A_1
A_4	A_4
A_{10}	A_9
A_8	A_7
A_7	A_{12}
A_{12}	A_{11}
A_{11}	A_8

CONCLUSION

Project management is an essential ingredient of business practices. Many researchers and practitioners have focused on flexibility of the critical path evaluation and various approaches are available for ranking of factors affecting the critical path. In general, critical path evaluation and selection problems are vague and so fuzzy set theory helps to convert decision making preferences and experiences into meaningful results by applying linguistic values to measure each criterion with respect to every expert. In this study, a combination fuzzy multi-criteria group decision making model has been developed by fuzzy set theory of the DM problems to select the best critical path so as to enable the oil group to achieve their business objectives in the project management practices. SIR.VIKOR is a best technique in MCDM; the obtained compromise solution could be accepted by the decision makers because it provides a max group utility of the majority and a minim of the individual regret of the opponent. Fuzzy AHP results show that four criteria as service, quality, delivery and cost have the greatest influence among the criteria and five criteria as past performance, flexibility, facility and technology ability have affecting on the critical path. Finally, results of SIR.VIKOR Method shows that two critical paths A_2 and A_6 are the best critical paths for oil group.

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