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Evaluation Criteria for Selecting Suppliers in the Field of Research With Fuzzy Multi-Criteria Approach

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Abstract. Today, there is no specific method or criterion for selecting contractors in the researches' field. Usually this selection is regarded as a matter of taste and as a result, there is no coordinated approach in the mentioned domain. Sometimes, after signing the contract, the inappropriate selection became clear. The managers are in direct need of a pattern for selecting the contractors. In the present research, the evaluation indexes of knowledge developers such as universities, knowledge-based companies, and research centers have been studied. For clarifying the process of the selection and by the help of the fuzzy TOPSIS method, we have considered four indexes as the general ones: 1) the price 2) the quality 3) the delivery time and 4) the work experiences. Finally, for better understanding, we have brought an example with 5 candidates and 5 determiners.

Keywords: Selecting of the Provider, Researches, Multi-Criteria Decision-Making, Fuzzy Numbers, TOPSIS.

1. Introduction and Literature Review

During the last two decades, managers have been witnessing a course of global changes as a result of technology progresses, globalization of markets, and new economical and political conditions. Due to an increase in the number of competitors in the world, the organizations have to quickly promote the inner-organization processes to stay in this global competition (Sherehiy et al., 2007). Today, outsourcing is one of the effective tools for increasing the efficiency of organizational activities, and also is regarded as the determiner of the organizational competitive advantage which is known as one of the simple strategic factor for promoting the organizational structures that helps to centralize the sources and capitals for basic activities (Perechuda & Sobińska, 2012). A lot of reasons exist to justify outsourcing which (Klepper at al., 2004) have classified them into tactical and strategic. The tactical reasons are increasing/decreasing the operational costs, the capital increase (outsourcing cause a reduction in investment in organizations' unnecessary activities). Noticing a lack of inner sources (the companies are doing outsourcing, because they do not have the necessary sources) .Omitting the troublesome issues (outsourcing is one of the ways for delegating the tasks which are out of control or difficult for the management). Increasing the liquidity (the reason is the in-cash payments for transferring the possessions from the organization to the provider) (Klepper et al., 2004).The strategic reasons for outsourcing are focusing on business improvement (outsourcing causes the organizations to focus on the basic activities, while the subsidiaries are done by the outer experts.) and accessing to the capabilities of the providers (the providers have sources and abilities to meet the needs of the clientele).

Taking the advantages of reorganization (usually, outsourcing is the subsidiary result of the redesigned business processes).

Sharing the risks with the providers (by outsourcing you share the risks with the providers). Redirecting the resources (outsourcing directs the organization's sources to the basic activities)(Klepper et al., 2004). Lacity et al. (2009) have provided a decision-matrix which includes the business, technological, and economical factors. These factors are the basis of decision-making for outsourcing the information-technology activities. Young et al (2000), emphasized on five factors for outsourcing-decisions which are management, strategy, economy, technology, and quality. They have used the hierarchical-analytical method for the outsourcing- problem structure and have suggested a decision-making model for selecting the outsourcing activities. Wang et al. (2007) have considered six factors of economy, strategic sources, risk, management, and quality. They also have applied the method of hierarchical analyzing and the promethean method to analyze the outsourcing structure and gauge the weight of criteria. The factors and criteria for outsourcing the research activities are various and complex which can be categorized as 1) initial criteria such as: saving money, saving time, etc. and 2) framework criterion; like executive and income criterion. (Howells et al.,2008)

2. Method

This model was presented by Hwang &Yoon in 1981. In this method, m number of n indexes is evaluated. The basic logic of this model introduces "the positive ideal solution" and "the negative ideal solution". The first is a solution which increases the criterion of benefit and decrease the criterion of cost. The negative ideal solution acts vice versa. The best choice is the one which is nearer to the first solution and is far from the second one. In other words, in choices ranking based on TOPSIS model, an option is the best when it is the most similar to the first solution. In this method, besides considering the distance of an object from the positive solution, its distance from the negative one is also studied (Ertugrul & Karakasoglu, 2009). Actually it is supposed that the index's perfection is not fixed, it may increase or decrease.

Whether a decision criterion is of cost- type and the aim is to decreasing it, or it is of benefit-type and the goal is to increasing it, compared to a model like AHP, TOPSIS finds the ideal answer which is the combination of the best solutions in reaching all the criteria. Here, a systematic approach to TOPSIS in a fuzzy environment is introduced. This method is appropriate for solving the group decision-making problems in the fuzzy environment. In this state, the importance of different criteria and ratings of qualitative criteria are done as linguistic variables. Totally, an algorithm of solving multi-criteria and multi-character decision-making problems is presented based on a fuzzy set approach.

Step 1: Identifying the Evaluation Criteria and the Appropriate Linguistic Variables

Suppose a committee includes of “k” deciders ($D^1, D^2, \ldots, D^k$) who are responsible for evaluating “m” choices ($A_1, A_2, \ldots, A_m$) based on “n” criteria:($C_1, C_2, \ldots, C_n$). The criteria are classified as costs (C) and benefits (B). Suppose that:

$$j = 1,2,\ldots,n; \quad x_{ij}^{t} \in R^{+};\ i = 1,2,\ldots,m; \quad x_{ij}^{t} = \left(a_{ij}^{t}, b_{ij}^{t}, c_{ij}^{t}\right) \tag{1}$$

There is a triangular fuzzy number which is equal to the score assigned to the A_i choice by the D^t decider based on the criterion C_j. Also suppose that:

$$t = 1,2,\ldots,k \qquad j = 1,2,\ldots,n; \quad w_{j}^{t} \in R^{+};\ w_{j}^{t} = \left(e_{j}^{t}, f_{j}^{t}, g_{j}^{t}\right) \tag{2}$$

There is a triangular fuzzy number which is equal to the weight assigned by the D^t decider based on the criterion C_j.

Step 2: Creating a normalized fuzzy decision-making matrix (NFDM)

As it is explained in the first step, the importance or weight of each criterion and the scoring of choices based on each criterion is calculated as follow (T. C. Chu, 2002):

$$x_{ij} = \frac{1}{k} (\times) \left[x_{ij}^{1} (+) x_{ij}^{2} (+) \ldots (+) x_{ij}^{k} \right]; \quad a_{ij} = \frac{1}{k} \sum_{t=1}^{k} a_{ij}^{t}; \quad b_{ij} = \frac{1}{k} \sum_{t=1}^{k} b_{ij}^{t}; \quad c_{ij}^{t} = \frac{1}{k} \sum_{t=1}^{k} a_{ij}^{t} \tag{3}$$

$$w_{j} = \frac{1}{k} (\times) \left[w_{j}^{1} (+) w_{j}^{2} (+) \ldots (+) w_{j}^{k} \right]; \quad e_{j} = \frac{1}{k} \sum_{t=1}^{k} e_{j}^{t}; \quad f_{j} = \frac{1}{k} \sum_{t=1}^{k} f_{j}^{t}; \quad g_{j}^{t} = \frac{1}{k} \sum_{t=1}^{k} g_{j}^{t} \tag{4}$$

As it is mentioned above, a fuzzy multi-criteria group decision-making problem can be indicated briefly in a matrix as follows:

$$DM = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ . & . & \cdots & . \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}; \qquad \tilde{W} = \left[w_{1}, w_{2}, \ldots, w_{n} \right]$$

To be sure of the compatibility between the average of the scores and the weights average we have to normalize them. By doing this, they are turned into comparable scales. To prevent complexity of the normalization formula in the classical TOPSIS, here we use linear scale or norm to converse the relative scales to various criteria. As a result, the normalized fuzzy decision matrix (U) will be calculated (T. C. Chu, 2002). Following, the matrix is calculated in this way:

$$\begin{aligned} c_{j}^{+} &= \underset{i}{Max}\, c_{ij}, && j \in B; \\ a_{j}^{-} &= \underset{i}{Min}\, a_{ij}, && j \in C; \\ \tilde{u}_{ij} &= \left(\frac{a_{ij}}{c_{j}^{+}}, \frac{b_{ij}}{c_{j}^{+}}, \frac{c_{ij}}{c_{j}^{+}} \right), && j \in B; \\ \tilde{u}_{ij} &= \left(\frac{a_{j}^{-}}{c_{ij}}, \frac{a_{j}^{-}}{b_{ij}}, \frac{a_{j}^{-}}{a_{ij}} \right), && j \in C \end{aligned} \tag{5}$$

According to the above-mentioned normalization method, the interval of the triangular fuzzy numbers is $\left[0,1\right]$

Step 3: Creating a Weighed Normalized Fuzzy Decision Matrix (WNFDM)

Based on the following equation, the WNFDM can be calculated.

$$\tilde{V} = \tilde{U} \left(\times \right) \tilde{W} \tag{6}$$

Step 4: Determining the Fuzzy Positive/Negative Ideal Solution

Knowing that $\tilde{v}_{ij}$ s are the normalized positive angular fuzzy numbers with the interval $\left[0,1\right]$,

So, the Positive/Negative Ideal Solutions are:

$$\begin{aligned} S^{+} &= \left(\tilde{v}_1^{+}, \tilde{v}_2^{+}, \ldots, \tilde{v}_n^{+} \right), \quad \tilde{v}_j^{+} = \left(\underset{i}{Max}\, \tilde{v}_{ij}^{a},\ \underset{i}{Max}\, \tilde{v}_{ij}^{b},\ \underset{i}{Max}\, \tilde{v}_{ij}^{c} \right) \\ S^{-} &= \left(\tilde{v}_1^{-}, \tilde{v}_2^{-}, \ldots, \tilde{v}_n^{-} \right), \quad \tilde{v}_j^{-} = \left(\underset{i}{Min}\, \tilde{v}_{ij}^{a},\ \underset{i}{Min}\, \tilde{v}_{ij}^{b},\ \underset{i}{Min}\, \tilde{v}_{ij}^{c} \right) \end{aligned} \tag{7}$$

Step 5: The Final Ranking of the Choices

In this stage, the coefficient of closeness is suggested for ranking of choices.

The Coefficient of Closeness (CC):

In this method, the choices' distance from positive S and negative S is calculated as follows:

Here, d_i^{+} is the distance of each choice from the positive ideal solution, and d_i^{-} is the distance of each choice from the negative ideal solution. So, it is as follow:

$$d_i^{+} = \sqrt{\sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^{+} \right)} \tag{8}$$

$$d_i^{-} = \sqrt{\sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^{-} \right)} \tag{9}$$

Then for choice ranking, their coefficient of closeness is calculated based on d_i^{+} and d_i^{-}:

$$d(\tilde{v}_{ij},\tilde{v}_j^+)=\left\{\left[\tilde{v}_{ij}^b-\underset{i}{Max}\ \tilde{v}_{ij}^b\right]^2+\left[(\tilde{v}_{ij}^b-\underset{i}{Max}\ \tilde{v}_{ij}^b)-(\tilde{v}_{ij}^a-\underset{i}{Max}\ \tilde{v}_{ij}^a)\right]^2 +\left[(\tilde{v}_{ij}^b-\underset{i}{Max}\ \tilde{v}_{ij}^b)-(\tilde{v}_{ij}^c-\underset{i}{Max}\ \tilde{v}_{ij}^c)\right]^2\right\} \quad (10)$$

$$d(\tilde{v}_{ij},\tilde{v}_j^-)=\left\{\left[\tilde{v}_{ij}^b-\underset{i}{Min}\ \tilde{v}_{ij}^b\right]^2+\left[(\tilde{v}_{ij}^b-\underset{i}{Min}\ \tilde{v}_{ij}^b)-(\tilde{v}_{ij}^a-\underset{i}{Min}\ \tilde{v}_{ij}^a)\right]^2 +\left[(\tilde{v}_{ij}^b-\underset{i}{Min}\ \tilde{v}_{ij}^b)-(\tilde{v}_{ij}^c-\underset{i}{Min}\ \tilde{v}_{ij}^c)\right]^2\right\} \quad (11)$$

It is clear that if the $A_i$choice is nearer to S^+ (the positive ideal solution) and is far from the S^- (the negative ideal solution), then the coefficient of closeness (CC_i) will go toward 1. Afterward, based on the amount of the coefficient of closeness, the choices can be ranked. Actually the more the coefficient of closeness, the higher the position in ranking.

3. Findings

Considering the four basic criteria (1.Price, 2.Quality, 3.Time of delivery and 4.Work experiences) as the decision-making ones, and five universities (1.Sharif University of Technology 2.Iran University of Science and Technology 3.KhajehNasirToosi University of Technology 4.Tehran University 5.Amirkabir University of Technology), the ideas of 5 main deciders about the importance of each decision-making criterion and their ideas about each provider are collected; each time based on a specific criterion and according to the 1& 2 questionnaire.

Step 1: Recognizing and Scoring of Criteria and Assigning Scores to each Choice based on Criteria:

The mentioned factors used in the model need carrying out a poll which have been done in two stages: In the first stage, the 7-point Likert scale is applied by using the linguistic variables in a 7-point

range S= {VL, L, ML, M, MH, H, and VH}. Each criterion is as follows: VL means “very low” with angular fuzzy numbers (0, 0, 0.1), L means “low” with angular fuzzy numbers (0, 0.1, 0.3), ML means “middle low” with angular fuzzy numbers (0.1, 0.3, 0.5), M means “middle” with angular fuzzy numbers (0.3, 0.5, 0.7), MH means “middle high” with angular fuzzy numbers (0.5, 0.7, 0.9), H means “high” with angular fuzzy numbers (0.7, 0.9, 1), and VH means “very low” with angular fuzzy numbers (0.9, 1, 1).

In the second stage, deciders score the 5 choices, each time focusing on a criterion and by the help of the linguistic variables in a 7-point range W= {VP, P, MP, F, MG, G, and VG} in which VP means “very powerless” with angular fuzzy numbers (0, 0, 1), P means “powerless” with angular fuzzy numbers (0, 1, 3), MP means “middle powerless” with angular fuzzy numbers (1, 3, 5), F means “middle” with angular fuzzy numbers (3, 5, 7), MG means “middle good” with angular fuzzy numbers (5, 7, 9), G means “good” with angular fuzzy numbers (7, 9, 10), and finally VG means “very good” with angular fuzzy numbers(9, 10, 10).

The 1&2 questionnaire is as follow based on the deciders’ ideas:

Table 1. 1st questionnaire: the deciders’ ideas about the importance of each criterion

criteria		Decision makers				
		D_1	D_2	D_3	D_4	D_5
price	C_1	H	M	MH	VH	H
quality	C_2	ML	L	M	MH	MH
Delivery time	C_3	H	M	MH	VH	MH
work experience	C_4	H	M	MH	H	H

The second questionnaire is about the deciders’ ideas about each provider; each time based on a specific criterion and according to the linguistic variables:

Table 2. 2nd questionnaire: the deciders' ideas about each provider based on a specific criterion

criteria		supplier	candidates	Decision makers				
				D_1	D_2	D_3	D_4	D_5
price	C_1	University 1	A_1	G	MG	F	VG	G
		University 2	A_2	P	VP	MP	F	VG
		University 3	A_3	MG	F	G	VG	VP
		University 4	A_4	F	P	MP	MG	F
		University 5	A_5	MG	MP	F	MG	VP
quality	C_2	University 1	A_1	G	F	G	VG	G
		University 2	A_2	G	F	MG	VG	VG
		University 3	A_3	MG	MP	F	G	MP
		University 4	A_4	G	F	MG	VG	MP
		University 5	A_5	MG	F	MG	G	VP
Delivery time	C_3	University 1	A_1	G	MG	G	VG	G
		University 2	A_2	F	P	MP	G	VG
		University 3	A_3	MP	P	P	F	P
		University 4	A_4	MG	F	MG	G	MP
		University 5	A_5	G	MG	G	VG	P
work experience	C_4	University 1	A_1	G	F	MG	VG	MG
		University 2	A_2	G	F	G	G	MG
		University 3	A_3	MG	P	F	MG	MG
		University 4	A_4	P	VP	MP	F	MG
		University 5	A_5	F	MP	F	G	MG

Step 2: Creating a normalized fuzzy decision-making matrix: (3) & (4) relations are used andthe data analysis of the taken polls is organized in the tables 1 and 2:

Table 3. the average of the criteria weights

criteria	Mean Normalized (W)		
C_1	0.62	0.80	0.92
C_2	0.28	0.46	0.66
C_3	0.58	0.76	0.90
C_4	0.58	0.78	0.92

Table 4. the average of the choices' weights; each time focusing on a criterion

criteria	candidates	Mean Normalized (U)		
C_1	A_1	0.64	0.82	0.94
	A_2	0.27	0.39	0.54
	A_3	0.49	0.64	0.76
	A_4	0.25	0.43	0.64
	A_5	0.29	0.45	0.64
C_2	A_1	0.68	0.86	0.96
	A_2	0.68	0.84	0.94
	A_3	0.35	0.56	0.74
	A_4	0.52	0.70	0.84
	A_5	0.41	0.58	0.74
C_3	A_1	0.72	0.90	1.00
	A_2	0.41	0.58	0.72
	A_3	0.09	0.23	0.43
	A_4	0.43	0.64	0.82
	A_5	0.58	0.74	0.86
C_4	A_1	0.60	0.78	0.92
	A_2	0.60	0.80	0.94
	A_3	0.37	0.56	0.76
	A_4	0.19	0.33	0.52
	A_5	0.39	0.60	0.78

Step 3: Creating a Weighed Normalized Fuzzy Decision Matrix: it is calculated based on (5) & (6) relations and the results are inserted in the table 5.

Table 5. the average of a weighed normalized

Candid / Criteria	Weighted Normalized Matrix											
	C_1			C_2			C_3			C_4		
A_1	0.40	0.66	0.86	0.19	0.40	0.63	0.42	0.68	0.90	0.35	0.61	0.85
A_2	0.17	0.31	0.50	0.19	0.39	0.62	0.24	0.44	0.65	0.35	0.62	0.86
A_3	0.30	0.51	0.70	0.10	0.26	0.49	0.05	0.17	0.39	0.21	0.44	0.70
A_4	0.16	0.34	0.59	0.15	0.32	0.55	0.25	0.49	0.74	0.11	0.26	0.48
A_5	0.18	0.36	0.59	0.11	0.27	0.49	0.34	0.56	0.77	0.23	0.47	0.72

Step 4: determining the ideal positive/negative solutions

In this step, the ideal positive/negative solutions is determined based on the (7) relation. The results are inserted in the table 6.

Table 6. The Amounts of the Ideal Positive/Negative Solutions

Candid / Criteria	Ideal solutions											
	C_1			C_2			C_3			C_4		
$\max(s^+)$	0.40	0.66	0.86	0.19	0.40	0.63	0.42	0.68	0.90	0.35	0.62	0.86
$\min(s^-)$	0.16	0.31	0.50	0.10	0.26	0.49	0.05	0.17	0.39	0.11	0.26	0.48

Step 5: in the final step the choices are ranked which the method of coefficient of closeness is suggested (as it was explained before).

Using the coefficient of closeness (CC): in this method di- and di+ are calculated based on (8), (9), (10), and (11) relations. The coefficient of closeness is also determined according to the (12) relation. By descending sort the amounts of CC_i (organizing from high to low), the corresponding position choices will be put in order. The results are inserted in table 7.

Table 7. The Positive/Negative Distances of Choices and their coefficient of closeness

Candid	d_i^+	d_i^-	CC_i	Rank
A_1	0.02	0.75	0.9713	1
A_2	0.44	0.50	0.5291	3
A_3	0.60	0.29	0.3223	5
A_4	0.55	0.35	0.3883	4
A_5	0.39	0.47	0.5429	2

Based on the calculations, the first developer is chosen with the highest score.

4. Conclusion

Today, there is no specific method or criterion for selecting contractors in the researches' field. Usually this selection is regarded as a matter of taste and as a result, there is no coordinated approach in the mentioned domain. Sometimes, after signing the contract, the inappropriate selection became clear. The managers are in direct need of a pattern for selecting the contractors.

Usually, the activities done out of the organization in the domain of selecting a research contractor are restricted to the scope of producing and providers of accessories, goods and material. One of the creative aspects of the present paper subject is the topic of contractor selection in the domain of research. As we are in lack of information resource in the field of the recent study, the considered criteria (price, quality, time of delivery, and experiences) are general and we did not enter into the details and sub-criteria. It is recommended to work on these details for further studies.

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