The Application of Fuzzy Group Decision Making Method on Contractor Selecting for Information System Outsourcing

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Abstract

IS Outsourcing has been prevailing over industries since the 90's. The failure of outsourcing harms not only the contractor but also the company. The pitfalls encountered in unsuccessful cases show that the contractor plays an important role in an outsourcing project. Therefore, the key factor of success in outsourcing greatly relies on selecting the right contractor. Using systematical method to resolve the conflict is a critical topic in group decision making.

The traditional and exact quantity method can not resolve the human-centric complexities, but fuzzy mathematical method is more proper than the traditional one in dealing with fuzzy problem.

In this research, we find out that during the process of multi-criteria or group decision making, Fuzzy Theory provides a systematical method of selecting a contractor through the process of fuzzy variables, fuzzy set and de-fuzzying to reach the optimal solution. Besides, empirical evidences show that price is not the most critical factor in selecting a contractor. The technical and supportive competences of the contractors are generally gave more weight to than are other criteria and are more valued by decision makers..

Keywords: *IS Outsourcing, Group decision making 、 Fuzzy theory, Fuzzy Multi-Attribute Decision Making*

1. Introduction

Since the '90s, IS Outsourcing has been prevailing among industries. A successful outsourcing project profits the company by lowering cost, improving service quality, strengthening core competence and focusing business. However, many unsuccessful cases hurt both the companies and the contractors. Most problems encountered in the outsourcing project are closely related to the contractor. Therefore, there is a close relationship between the selection of the contractor and the result of a outsourcing project.

Traditionally, the selection of a contractor depends on experience or committee. The drawbacks is that selection is mostly rely on individual subjective perception and lacks of systematical decision making. Usually there are conflicts between the members of the committee and an agreement can not be reached. How to resolve the conflict is a critical topic in group decision making [1, 5, 8, 17]. Systematical decision making process is regarded as a path to resolve conflicts and reach agreements. There are many criteria assessment methods such as Analytic Hierarchy Process(AHP) , Fuzzy Theory , Fuzzy Analytic Hierarchy Process(FAHP) , Fuzzy Delphi Method, studied and applied by academia. The traditional precise quantitative method can not completely resolve complex human-centric problems, whereas, fuzzy mathematical analysis method is more adequate in dealing with fuzzy problems. In this study, we intend to apply Fuzzy theory to multi-attribute decision making on selecting IS Outsourcing contractor and expect to establish the weight of each criterion in selecting contractors.

2. The Common Problems in IS Outsourcing

Managers often have to make decisions whether to outsource the IS or to develop by themselves [22]. Once them decide to outsource, they encounter the next decision of selecting the contractor. Jung [13] indicated some problems often happen in outsourcing projects(as shown in Table 2). Most of the problems are closely related to the contractors.

Table 2
Common problems in IS outsourcing

Problem	Description
Difficult to select a competent contractor	It is difficult to know a contractor's quality, capacity, competence, financial status and stability
Can not complete the project	The contractor can not accomplish the project due to technical, financial or managerial problem
Quality of projects are unexpected	The functions are incomplete or unreliable due to contractor's capacity of duties.
Delayed schedule	Schedules are delayed due to contractor's incompetence or change of project members.
Projects are unworthy to maintain	The maintenance cost is so high due to improper planning or development that it is not worth to maintain.
The contractors can not	The contractors can not meet

meet companies' requirements	companies' requirements or the contracts and companies get into the dilemma of advance or retreat.
Overspending	The spending exceeds the budget

3. Fuzzy Theory and Fuzzy Multi-Attribute Decision Making

3.1 The basic concepts of fuzzy numbers

In Fuzzy Theory, Zadeh [23] uses mathematic model to represent the uncertainty in human cognition process, thinking and critical reasoning. The theory expands the classical mathematics from Binary logic, right and wrong, to the gray area of Continuous multi-value logic. Fuzzy Set means to build Membership Function among things that have vague boundaries but certain characters to represent the concept. It is a "double-faced" concept. The point is that the traditional and exact quantity method can not resolve the human-centric complexities, but fuzzy mathematical method is more appropriate than the traditional one in dealing with fuzzy problem.

Fuzzy set theory is widely applied in social sciences [10, 12], management [4, 9], and academic research aspects [18] so forth. In recent years, some researches on the application of fuzzy set theory in decision have begun [2, 3, 7, 11, 16, 19, 21]. In the following, some basic definitions of fuzzy set theory [4] will be addressed.

Let X be the universe of discourse, $X = \{x_1, x_2, ..., x_n\}$. A fuzzy set $\tilde{A}$ of X is a set of order pairs $\{(x_1, u_{\tilde{A}}(x_1)), (x_2, u_{\tilde{A}}(x_2)), ..., (x_n, u_{\tilde{A}}(x_n))\}$, $u_{\tilde{A}}: X \to [0,1]$, is the membership function of $\tilde{A}$, and $u_{\tilde{A}}(x_i)$ presents the membership degree of x_i in $\tilde{A}$. The following descriptions and definitions show that membership function of triangular and trapezoidal fuzzy number, and its operators.

Definition 1. A fuzzy number $\tilde{A}$ is convex [14], if

$$u_{\tilde{A}}[\lambda x_1 + (1-\lambda)x_2] \geq \min[u_{\tilde{A}}(x_1), u_{\tilde{A}}(x_2)], \quad x_1, x_2 \in X, \ \lambda \in [0,1] \tag{1}$$

Alternatively, a fuzzy set is convex if all α-level sets are convex.

Definition 2. A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal [4].

One of the most important concepts of fuzzy sets is the concept of an α-cut and its variant. It is a bridge from well-defined structure to fuzzy environment.

Definition 3. A triangular fuzzy number can define as triplet (a_1, a_2, a_3). Its membership function is defined as

$$f_{\tilde{A}}(x) = \begin{cases} 0, & x < a_1 \\ (x-a_1)/(a_2-a_1), & a_1 \leq x \leq a_2 \\ (a_3-x)/(a_3-a_2), & a_2 \leq x \leq a_3 \\ 0, & x > a_3 \end{cases} \tag{2}$$

Definition 4. Let $\tilde{A}$ and $\tilde{B}$ be two fuzzy numbers parameterized by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), then the operations (addition, subtraction, multiplication and division) of triangular fuzzy numbers [4] are performed as:

$$\tilde{A}(+)\tilde{B} = (a_1, a_2, a_3) + (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \tag{3}$$

$$\tilde{A}(-)\tilde{B} = (a_1, a_2, a_3) - (b_1, b_2, b_3) = (a_1 - b_3, a_2 - b_2, a_3 - b_1) \tag{4}$$

$$\tilde{A}(\times)\tilde{B} = (a_1, a_2, a_3) \times (b_1, b_2, b_3) = (a_1 b_1, a_2 b_2, a_3 b_3) \tag{5}$$

$$\tilde{A}(\div)\tilde{B} = (a_1, a_2, a_3) \div (b_1, b_2, b_3) = (a_1 / b_3, a_2 / b_2, a_3 / b_1) \tag{6}$$

$$r(\times)\tilde{A} = (ra_1, ra_2, ra_3) \tag{7}$$

$$r(+)\tilde{A} = (r + a_1, r + a_2, r + a_3) \tag{8}$$

3.2 Fuzzy Multi-Attribute Decision Making

In Wang and Chang's study [20], they proposed an approach to the tool steel selection problem. This approach is particularly useful for making decision under fuzzy environment. The methodology and algorithm is described as follows.

Step 1：Assign the membership functions for linguistic weighting values

In [20], Wang and Chang used five fuzzy linguistic hedges for tool steel evaluation, i.e., VL (very low), L (low), M (medium), H (high) and VH (very high), where

VL=(0,0,0,0.3)	L=(0,0.3,0.3,0.5)
M=(0.2,0.5,0.5,0.8)	H=(0.5,0.7,0.7,1)
VH=(0.7,1,1,1)	

The membership functions of the five linguistic values as shown in Fig. 1.

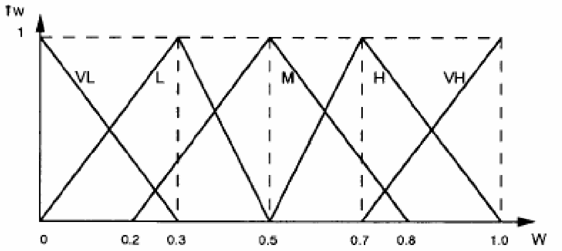

Fig. 1. Membership functions for linguistic weighting values

Step 2：Assign the membership functions for linguistic rating values

There are five fuzzy linguistic rating hedges used for each criteria, i.e., W (worst), P (poor), F (fair), G (good) and B (best),in [20], where

W=(0,0,0,0.3) P=(0,0.3,0.3,0.5)
F=(0.2,0.5,0.5,0.8) G=(0.5,0.7,0.7,1)
B=(0.7,1,1,1)

The membership functions of the five linguistic rating values as shown in Fig. 2.

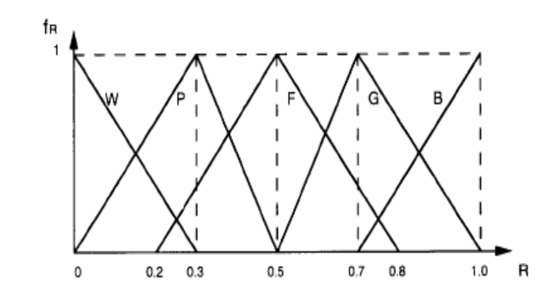

Fig. 2. Membership functions for linguistic rating values

Step 3：Decided the evaluated criteria.

Step 4：Evaluating the importance of different selection criteria.

Aggregate the n decision makers' opinions.

$$W_t = \frac{1}{n} \otimes (W_{t1} \oplus W_{t2} \oplus .... \oplus W_{tn}) \qquad t = 1,2,......,k \qquad (9)$$

where

W_t ：the aggregated weighting for criterion t

W_{tn} ：the importance weighting given by decision maker n to criterion t

k ：the number of criteria.

Step 5：Evaluating R_{it} of alternative i under criterion t

$$R_{it} = \frac{1}{n} \otimes (R_{it1} \oplus R_{it2} \oplus ...... \oplus R_{itn}) \qquad i = 1,2,.....,m;\ t = 1,2,.....,k \qquad (10)$$

$i = 1, 2, ..., m$

m ：the number of alternative

$t = 1, 2, ..., k$

k ：the number of criteria

R_{itn} : the assigned rating of alternative i under criterion t by decision maker n .

Step 6：To obtain the final rating F_i for each alternative

After the weights and ratings have been assigned and aggregated, each aggregated rating of alternative i and criterion t , (R_{it})can further be weighted by the aggregated weight (W_t) to obtain the final rating (F_i).

$$F_i = \frac{1}{k} \otimes [(R_{i1} \otimes W_1) \oplus (R_{i2} \otimes W_2) \oplus .... \oplus (R_{ik} \otimes W_k)] \qquad (11)$$

Step 7：Defuzzify fuzzy number and ranking

The process converting a fuzzy number into a crisp value is called defuzzify. Various defuzzification strategies were suggested, in this paper, Cheng's [6] method of maximizing set and minimizing set is applied.

The maximizing set is defined as:

$M = \{(x, f_M(x)) \mid x \in R\}$, with the membership function

$$f_M(x) = \begin{cases} (x - x_1)/(x_2 - x_1), x_1 \le x \le x_2, \\ 0, \qquad otherwise \end{cases} \qquad (12)$$

Similarly, the minimizing set is defined as:

$G = \{(x, f_G(x)) \mid x \in R\}$, with the membership function

$$f_G(x) = \begin{cases} (x - x_2)/(x_1 - x_2), x_1 \le x \le x_2, \\ 0, \qquad otherwise \end{cases} \qquad (13)$$

Then the right utility $U_M(F_i)$ and left utility $U_G(F_i)$ can be denoted as:

$$U_M(F_i) = \sup_x (f_{F_i}(x) \wedge f_M(x)) \qquad (14)$$

$$U_G(F_i) = \sup_x (f_{F_i}(x) \wedge f_G(x)) \qquad (15)$$

As a result, the crisp value can be obtained by combining the right and left utilities.

$$U_T(F_i) = [U_M(F_i) + 1 - U_G(F_i)]/2 \qquad (16)$$

The bigger value presents the better performance of the alternative.

4. Contractor selecting for information system outsourcing

In this section, the fuzzy group decision making method presented in our research is applied form an example problem to select the contractor of IS outsourcing, which may be implemented under multiple decision criteria.

The problem is as follow. The selection of the best contractor of IS outsourcing is a decision goal. Four vendors（V_1-V_4） ate considered as decision alternatives. There are four decision makers（D_1-D_4）will evaluate the vendors under seven criteria（C_1-C_7）.

Step 1：Assign the membership functions for linguistic weighting values

We used five fuzzy linguistic weighting hedges for each criteria, i.e., VL (very low), L (low), M (medium), H (high) and VH (very high), where

VL=(0,0,0,0.3)   L=(0,0.3,0.3,0.5)
M=(0.2,0.5,0.5,0.8)   H=(0.5,0.7,0.7,1)
VH=(0.7,1,1,1)

Step 2：Assign the membership functions for linguistic rating values

We used five fuzzy linguistic rating hedges for each criteria, i.e., W (worst), P (poor), F (fair), G (good) and B (best) also defined in [20], where

W=(0,0,0,0.3)   P=(0,0.3,0.3,0.5)
F=(0.2,0.5,0.5,0.8)
G=(0.5,0.7,0.7,1)   B=(0.7,1,1,1)

Step 3：Decided the evaluated criteria.

In accordance with Lu's [15] research in 2000, we have revised some attributes which proposed by Lu, then evaluate vendors by the modified decision criteria . The decision criteria as shown in Table 3.

Table 3.
The decision criteria for selecting contractor of IS outsourcing

Criteria	Description
experience (EXP)	Knowledge about customers' industry The developed experience about similar information systems A market share The quantity and quality of engineers
goodwill (GOW)	The stability of financial affairs Reputation Circumstance about keep business secret
The ability of co-operation (COP)	Ability of integrate systems Local or overseas vendors
The ability of technology (TEC)	Ability of software Ability of hardware Ability of data communication Ability of data security Tool of system development Ability of R & D
The ability of supporting (SUP)	Training Enterprise's scope Culture of enterprise Location of enterprise
The ability of management (MAG)	Quality of documents Documents Ability to execute project Delivery date and items Procedure of QA Ability of project management
Common problems (COM)	Price Response Expectable benefit

Step 4：The decision makers evaluate the importance of different selection criteria.

The result as shown in Table 4 and Table 5.

Table 4.
The importance weight of the linguistic criteria

	Decision maker			
Criteria	D_1	D_2	D_3	D_4
EXP	VH	VH	H	H
GOW	H	VH	M	H
COP	VH	VH	H	H
TEC	VH	VH	H	VH
SUP	VH	VH	H	VH
MAG	H	H	M	H
COM	VH	H	L	M

Table 5.
The importance weight fuzzy number of the linguistic criteria

	Decision maker			
Cri.	D_1	D_2	D_3	D_4
EXP	(0.7,1,1,1)	(0.7,1,1,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)
GOW	(0.5,0.7,0.7,1)	(0.7,1,1,1)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)
COP	(0.7,1,1,1)	(0.7,1,1,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)
TEC	(0.7,1,1,1)	(0.7,1,1,1)	(0.5,0.7,0.7,1)	(0.7,1,1,1)
SUP	(0.7,1,1,1)	(0.7,1,1,1)	(0.5,0.7,0.7,1)	(0.7,1,1,1)
MAG	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)
COM	(0.7,1,1,1)	(0.5,0.7,0.7,1)	(0,0.3,0.3,0.5)	(0.2,0.5,0.5,0.8)

Aggregate 4 decision makers' opinions by Eq. (9).

$$W_1 = \frac{1}{4} \otimes \left[(0.7,1,1,1) \oplus (0.7,1,1,1) \oplus (0.5,0.7,0.7,1) \oplus (0.5,0.7,0.7,1)\right] = (0.6, 0.85, 0.85, 1)$$

$$W_2 = (0.48, 0.725, 0.725, 0.95)$$
$$W_3 = (0.6, 0.85, 0.85, 1)$$

$W_4 = (0.65, 0.925, 0.925, 1)$
$W_5 = (0.65, 0.925, 0.925, 1)$
$W_6 = (0.425, 0.65, 0.65, 0.95)$
$W_7 = (0.35, 0.625, 0.625, 0.825)$

Step 5：Evaluating R_{it} of alternative i under criterion t

The result as shown in Table 6,Table 7 and Table 8.

Table 6.
The evaluated result for each alternative by decision maker

Alternative	V_1				V_2				V_3				V_4			
Decision maker	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
EXP	**G**	**G**	**F**	**F**	**G**	**G**	**G**	**F**	**F**	**F**	**F**	**G**	**F**	**F**	**F**	**F**
GOW	**G**	**G**	**G**	**G**	**G**	**G**	**G**	**G**	**F**	**G**	**F**	**F**	**F**	**G**	**F**	**F**
COP	**G**	**G**	**G**	**G**	**G**	**B**	**G**	**G**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
TEC	**G**	**F**	**F**	**F**	**F**	**G**	**G**	**G**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
SUP	**G**	**G**	**G**	**F**	**F**	**G**	**G**	**G**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
MAG	**G**	**F**	**F**	**G**	**F**	**G**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
COM	**G**	**G**	**G**	**G**	**F**	**G**	**F**	**G**	**P**	**F**	**F**	**F**	**P**	**F**	**F**	**F**

Table 7.
The evaluated fuzzy number for each alternative by decision maker（V_1, V_2）

Alt.	V_1				V_2			
D.M.	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
EXP	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)
GOW	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)
COP	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.7,1,1,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)
TEC	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)
SUP	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)
MAG	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
COM	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)

Table 8.
The evaluated fuzzy number for each alternative by decision maker（V_3,V_4）

Alt.	V_3				V_4			
D.M.	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
EXP	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
GOW	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.5,0.7,0.7,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
COP	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
TEC	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
SUP	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
MAG	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
COM	(0,0.3,0.3,0.5)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0,0.3,0.3,0.5)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)

Aggregate the 4 decision makers' opinions by Eq. (10) (as shown in Table 9).

Table. 9.
Aggregated fuzzy decision matrix

Alternative	V_1	V_2	V_3	V_4
EXP	(0.35,0.6,0.6,0.9)	(0.43,0.65,0.65,0.95)	(0.28,0.55,0.55,0.85)	(0.2,0.5,0.5,0.8)
GOW	(0.5,0.7,0.7,1)	(0.5,0.7,0.7,1)	(0.28,0.55,0.55,0.85)	(0.28,0.55,0.55,0.85)
COP	(0.5,0.7,0.7,1)	(0.55,0.78,0.78,1)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
TEC	(0.28,0.55,0.55,0.85)	(0.43,0.65,0.65,0.95)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
SUP	(0.43,0.65,0.65,0.95)	(0.43,0.65,0.65,0.95)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
MAG	(0.35,0.6,0.6,0.9)	(0.28,0.55,0.55,0.85)	(0.2,0.5,0.5,0.8)	(0.2,0.5,0.5,0.8)
COM	(0.5,0.7,0.7,1)	(0.35,0.6,0.6,0.9)	(0.15,0.45,0.45,0.73)	(0.15,0.45,0.45,0.73)

Step 6：To obtain the final rating F_i for each alternative

By Eq. (11), F_i can be seen in as follow:

$$F_1 = \frac{1}{7} \otimes \begin{bmatrix} (0.35, 0.6, 0.6, 0.9) \otimes (0.6, 0.85, 0.85, 1) \oplus (0.5, 0.7, 0.7, 1) \otimes (0.48, 0.725, 0.725, 0.95) \\ \oplus (0.5, 0.7, 0.7, 1) \otimes (0.6, 0.85, 0.85, 1) \oplus (0.275, 0.55, 0.55, 0.85) \otimes (0.65, 0.925, 0.925, 1) \\ \oplus (0.425, 0.65, 0.65, 0.95) \otimes (0.65, 0.925, 0.925, 1) \oplus (0.35, 0.6, 0.6, 0.9) \otimes (0.425, 0.65, 0.65, 0.95) \\ \oplus (0.5, 0.7, 0.7, 1) \otimes (0.35, 0.625, 0.625, 0.825) \end{bmatrix}$$

$$= (0.2184, 0.5071, 0.5071, 0.9043)$$

$$F_2 = (0.2310, 0.5220, 0.5220, 0.9071)$$
$$F_3 = (0.1164, 0.4043, 0.4043, 0.7737)$$
$$F_4 = (0.1099, 0.3983, 0.3983, 0.7665)$$

Step 7：Defuzzify triangular fuzzy number and ranking

The triangular fuzzy number F_i is defuzzified into crisp number with Eqs. (12)-(16), and the values are displayed in Table 10.By Eq. (12)-(16), then the best contractor can be find out.

Table 10.
The values of index Ut and rank for alternative

	l	m	m	r	Um	Ug	Ut	Rank
V_1	0.2184	0.5071	0.5071	0.9043	0.6651	0.6342	0.5154	2
V_2	0.2310	0.5220	0.5220	0.9071	0.6743	0.6213	0.5265	1
V_3	0.1164	0.4043	0.4043	0.7737	0.5690	0.7287	0.4202	3
V_4	0.1099	0.3983	0.3983	0.7665	0.5634	0.7343	0.4145	4

As stated in Table 10, the bigger value of the index Ut implies the better performance of the candidate. Hence, the ranking order is $V_2 > V_1 > V_3 > V_4$, V_2 is given precedence over V_1 , V_3 and V_4.

5. Conclusions

In this research we find out that during the process of multi-criteria or group decision making, Fuzzy Theory provides a systematical method of selecting a contractor through the process of fuzzy variables, fuzzy set and de-fuzzying to reach the optimal solution. Besides, empirical evidences show that price is not the most critical factor in selecting a contractor. The technical and supportive competences of the contractors are generally gave more weight to than are other criteria and are more valued by decision makers.

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