Fuzzy Method for Project Success Achievement

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Abstract:

The aim of this study is to propose a new method to define weights for projects activities to achieve comprehensive and accurate progress that makes the managers make accurate decisions. Methods previously explored by researchers are not exhaustive and they cannot consider all of projects success criteria, and they are not preferable by all projects main elements, too. The proposed method uses the Fuzzy MCDM methods to define the relative criteria weights to attain activity weights by using all of project success variables as quantitative or qualitative ones. The vagueness of any criterion such as human habits and project types that are considerable in this method and more flexibility and comprehensiveness achieved in the method, indicate the preference of our method to the traditional ones. Empirical results show the viability of the proposed method.

Keywords: Project success, S-curve, Fuzzy MCDM, Hypothesis.

Introduction and literature review

Schedule, cost and quality are three traditional main criteria, directly affect the project success [1[3]. So, a near scheduled or near budgeted project which is considered to indicate a suitable level of performance is called successful just because of its simplicity. But these assessments are not comprehensive [2]. Schedule and cost are so close. So, several researchers have been proposing models to combine them [4].

Beside the cost, several researchers explore human factor as a main criterion of project success and define it as one of the major limitations of predefined methods [1]. Some researchers introduce type of project [5] and some of them introduce customer satisfaction as project success factor [6].

In addition, the success is funded as a multi-dimensional multi-criteria approach, related to diverse views of different peoples [2], [5[7] and even changes with time [2], [6] and some researchers point out that payment to contractors; especially in construction projects, is the other main parameter in project success that is based on project progress measurement, like the other factors and it is the most important dispute between owner and contractor [8].

In progress measurement, there are two main methods named as Milestones and BOQ methods where contractor prefers the BOQ method and owner prefers the other one. It is proved that there is significant difference between these two methods and it is the challenge [8].

Previous paragraphs reveal the weakness of traditional concepts in the case of project management and success. So the necessity of describing a new method to consider all crucial parameters or a group of them is clear. In this paper a new advanced weighting method is introduced. This method considers all critical factors to achieve the advanced reliable progress measurement as project success. In this method, we use AHP and TOPSIS models to combine all main parameters and integrate relative weights whether they are qualitative or not. Besides, we use these two methods in fuzzy base to deal with any imprecision that may be confronted.

Principles of Fuzzy Group Analytic Hierarchy Process Model

AHP, introduced by Saaty [9], [10] is a MCDM method that can determine the priorities among various criteria [11] and then the fuzzy theory investigated to confront uncertainties [12[14]. Beside, researchers explore that decision making may establish on multi-decision makers (DMs) views [15]. So our study uses Fuzzy Group AHP method to assess a weight of each crucial criterion that affects the activity priority. The method of this theory is shown as below:

(1) Translating the problem into a hierarchy with a top goal, criteria, sub-criteria and decision alternatives [15[17].

(2) Constructing pairwise comparison matrix that may alternatively contain triangular linguistic fuzzy numbers [10], [15], [16]as follows (*k* is the counter of DMs):

$$D^k = \begin{bmatrix} x_{11}^k & \dots & x_{1n}^k \\ \vdots & \ddots & \vdots \\ x_{n1}^k & \dots & x_{nn}^k \end{bmatrix} \quad (1)$$

(3) Calculating eigenvector and λ_{max} by Eq. (2) and define consistency index for each decision matrix by Eq. (3) to validate the related DM [11], [15], [16].

$$|D - \lambda.I| = 0 \quad (2)$$

$$CI = \lambda_{max} - n \Big/ n - 1 \quad (3)$$

(4) Extracting comparative weight of each criterion by Eigenvector technique [15]. In this way, define matrix D by Eq. (4) [10], [15], Then using increasing power η for matrix D and normalizing the result by Eq. (5) until achieving the consistency in W, Where $\xi = [1 \quad 1 \quad \cdots \quad 1]^t$ [15].

$$(D - \lambda_{max} I)W = 0 \quad (4)$$

$$W = \lim_{\xi \longrightarrow \infty} \left(D^\eta.\xi \Big/ \xi^t.D^\eta.\xi \right) \quad (5)$$

(5) Transforming the comparative weights to fuzzy triangular numbers that may be defined by triplet (a_1, a_2, a_3) by using Eq. (6) [10], [16], [17] and the rule of thumb illustrated in Table 1.

$$\mu_{\tilde{w}}(w) = \begin{cases} 0 & w \le a_1 \\ w - a_1 \Big/ a_2 - a_1 & a_1 \le w \le a_2 \\ a_3 - w \Big/ a_3 - a_2 & a_2 \le w \le a_3 \\ 1 & w > a_3 \end{cases} \quad (6)$$

Table 1
Rule-of-thumb transformation table

Rank	Membership Function
Very Low (VL)	(0.00,0.10,0.25)
Low (L)	(0.15,0.30,0.45)
Medium (M)	(0.35,0.50,0.65)
High (H)	(0.55,0.70,0.85)
Very High (H)	(0.75,0.90,1.00)

(6) Having conductive weight of all DMs, using the notion of average value by using of Eq. (7) [10], [14], [16]:

$$\odot\, \tilde{w}_i = \frac{1}{m} \odot (\tilde{w}_i^1 \oplus \tilde{w}_i^2 \oplus \ldots \oplus \tilde{w}_i^m) \tag{7}$$

Principles of Fuzzy TOPSIS

Hwang and Yoon proposed TOPSIS model to order performance by similarity to ideal solution. Criteria weights that previously consigned by FGAHP are the only necessary input of model [19]. In this method, it is difficult for DMs to assign accurate performance rating to alternatives. This inaccuracy worsened by increasing in subjectivity of judgment that makes the classical TOPSIS inefficient. Thus, fuzzy theory has been used to confront this vagueness and make the decision making close to the real world [20]. The process of this model is shown as below:

(1) defining fuzzy decision matrix as shown below [16]:

$$D = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{8}$$

$$\tilde{x}_{ij} = \frac{1}{K}(\tilde{x}_{ij}^1 \oplus \tilde{x}_{ij}^2 \oplus \ldots \oplus \tilde{x}_{ij}^k \oplus \ldots \oplus \tilde{x}_{ij}^K) \tag{9}$$

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n) \tag{10}$$

Where $\tilde{x}_{ij}^k$ is fuzzy performance rating of activity A_i related to j^{th} criterion and assigned by k^{th} DM. $\tilde{x}_{ij}$ is integrated fuzzy triangular performance rating of activity A_i related to j^{th} criterion expressed by Eq.(6). $\tilde{W}$ is fuzzy weight of criteria [16], [18].

(2) Normalizing the fuzzy decision matrix by using Eq.(11).

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n} \quad i = 1,2,\ldots,m \text{ and } j = 1,2,\ldots,n \tag{11}$$

(3) Calculating fuzzy normalized decision matrix as shown in Eq.(12) and then defining fuzzy negative and fuzzy positive ideals as $\tilde{v}_j^- = (0,0,0)$ and $\tilde{v}_j^+ = (1,1,1)$ and $j = 1,2,\ldots,n$

$$V = \begin{bmatrix} \tilde{v}_{11} & \cdots & \tilde{v}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{v}_{m1} & \cdots & \tilde{v}_{mn} \end{bmatrix} = \begin{bmatrix} \tilde{w}_1 \tilde{r}_{11} & \cdots & \tilde{w}_n \tilde{r}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{w}_1 \tilde{r}_{m1} & \cdots & \tilde{w}_n \tilde{r}_{mn} \end{bmatrix} \tag{12}$$

(4) Calculating the distance of each activity from fuzzy negative and fuzzy positive ideals by using Eq.(13) and Eq.(14).

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1,2,...,m \quad (13)$$

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+), i = 1,2,...,m \quad (14)$$

(5) Calculating the closeness coefficients by using Eq.(15) [16], [18] and [19].

$$C_i = \frac{d_i^-}{d_i^+ - d_i^-} \quad (15)$$

Empirical example

As an empirical study, we propose one stadium as a sample of construction projects to demonstrate usefulness and validity of the proposed method. The data for this study were collected in winter 2010 in Iran. The project contains 121 activities in 4 WBS levels when three types of DMs were asked for establishing WBS and time-scaled plan in MSP software. Evaluation process is demonstrated as follows:

FGAHP in practice

(1) The hierarchical structure is portrayed in Fig. 1.

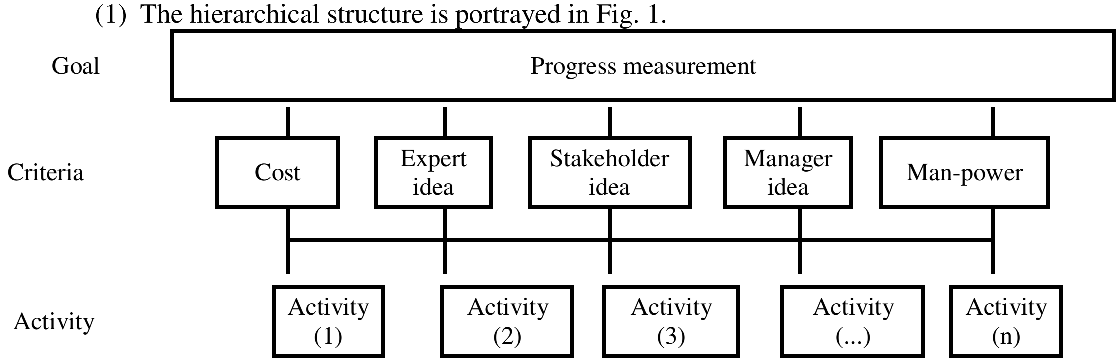

Fig. 1. The case study problem's decision-making hierarchy

(2) DM's judgment about criteria, λ_{max} and CI for all three DMs calculated by MATLAB software are illustrated in Table 2.

Table 2
Three DMs pairwise comparison matrix of criterion

DM^{1,2,3}	Cost (BCWP)			Experts Idea			Stakeholder Idea			Manager Idea			Man-power		
	DM			DM			DM			DM			DM		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Cost (BCWP)	1	1	1	5	2	0.5	3	2	0.5	3	5	0.6	7	7	0.2
Experts Idea	0.2	0.5	2	1	1	1	1/3	0.5	3	0.5	3	5	2	2	1
Stakeholder Idea	1/3	0.5	2	3	2	1/3	1	1	1	2	3	1	3	5	0.5
Manager Idea	1/3	0.2	1/0.6	2	0.5	0.2	0.5	0.2	1	1	1	1	2	2	0.5
Man-power	1/7	1/7	5	0.5	0.5	1	1/3	0.2	2	0.5	0.5	2	1	1	1

DM^1	λ_{max} : 5.0877555234	CI: 0.0219388
DM^2	λ_{max} : 5.0997601918	CI: 0.0249400
DM^3	λ_{max} : 5.2331000000	CI: 0.0582750

By using Eq. (5), and MATLAB software, we were achieving the weights related to each DM and cumulative weight of criteria as below:

W=(0.4355,0.1317,0.1983,0.1285,0.1060) (16)

(3) By using rule of thumb, we were achieving fuzzy weights and linguistic variables.

(4) We were integrating three DM judgments by using Eq. (7). The result is shown in Table 3.

Table 3
Integrated fuzzy criteria weights

	Fuzzy weight ($\tilde{w}$)
Cost (BCWP) $\tilde{w}_1$	(0.35,0.50,0.65)
Experts Idea $\tilde{w}_2$	(0.00,0.10,0.25)
Stakeholder Idea $\tilde{w}_3$	(0.10,0.23,0.38)
Manager Idea $\tilde{w}_4$	(0.00,0.10,0.25)
Man-power $\tilde{w}_5$	(0.00,0.10,0.25)

FTOPSIS in practice

(1) We were gathering DMs ideas by using the format illustrated in Table 4.

Table 4
Data gathering raw format

	Cost	Experts Idea	Stakeholder Idea	Manager Idea	man-power
Activities	Quantitative	Qualitative			Quantitative
A_1					
⋮					
A_{121}					

Qualitative criteria must be rated In linguistic parameters, as shown below:			
Absolutely important	AI	Unimportant	U
Important	I	Absolutely unimportant	AU
More or less important	ML		

We were using Five-point Likert to transform quantitative performance ratings to qualitative ones.

(2) We were normalizing the qualitative ratings by using Eq. (17) for the larger the better type and Eq. (18) for the smaller the better type, rule of thumbs, has been used and finally we were integrating data by using Eq. (9). Subsequently, we were calculating fuzzy weighted decision matrix and fuzzy negative and positive ideals. The results of these steps are summarized in Table 5.

$$r_{ij} = \frac{[x_{ij} - \min\{x_{ij}\}]}{[\max\{x_{ij}\} - \min\{x_{ij}\}]} \quad (17)$$

$$r_{ij} = \frac{[\max\{x_{ij}\} - x_{ij}]}{[\max\{x_{ij}\} - \min\{x_{ij}\}]} \quad (18)$$

Table 5
Summary of Fuzzy weighted decision matrix

	Cost	Expert Idea	Stakeholder Idea	Manager Idea	Man-power
A_1	(0.00,0.05,0.16)	(0.00,0.03,0.11)	(0.02,0.07,0.17)	(0.00,0.01,0.06)	(0.00,0.05,0.16)
A_2	(0.00,0.05,0.16)	(0.00,0.03,0.11)	(0.02,0.07,0.17)	(0.00,0.01,0.06)	(0.00,0.07,0.21)
A_3	(0.00,0.05,0.16)	(0.00,0.01,0.06)	(0.00,0.02,0.10)	(0.00,0.01,0.06)	(0.00,0.07,0.21)
A_4	(0.00,0.05,0.16)	(0.00,0.05,0.16)	(0.00,0.02,0.10)	(0.00,0.01,0.06)	(0.00,0.07,0.21)
A_5	(0.05,0.15,0.29)	(0.00,0.05,0.16)	(0.02,0.07,0.17)	(0.00,0.01,0.06)	(0.00,0.07,0.21)
⋮	⋮	⋮	⋮	⋮	⋮
A_{118}	(0.00,0.05,0.16)	(0.00,0.03,0.11)	(0.02,0.07,0.17)	(0.00,0.01,0.06)	(0.00,0.05,0.16)
A_{119}	(0.00,0.05,0.16)	(0.00,0.01,0.06)	(0.04,0.12,0.25)	(0.00,0.01,0.06)	(0.00,0.03,0.11)
A_{120}	(0.00,0.05,0.16)	(0.00,0.03,0.11)	(0.02,0.07,0.17)	(0.00,0.01,0.06)	(0.00,0.03,0.11)
A_{121}	(0.00,0.05,0.16)	(0.00,0.01,0.06)	(0.02,0.07,0.17)	(0.00,0.01,0.06)	(0.00,0.03,0.11)
$\tilde{v}_j^+$	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
$\tilde{v}_j^-$	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)

(3) We were calculating the distance between each activity from the fuzzy negative and fuzzy positive ideals by using Eq.(13) and Eq.(14) And subsequently, we were using Eq. (15) to obtain the closeness coefficients. After normalizing, the coefficients could be used as the weight of each activity. The results of this calculation have been showing in Table 6.

Table 6
FMCDM results and activities weights

A	W_i	A	W_i	A	W_i	A	W_i	A	W_i	A	W_i
1	0.78	21	0.78	41	0.94	61	0.85	81	0.84	101	0.76
2	0.84	22	1.63	42	0.94	62	0.84	82	0.9	102	0.72
3	0.69	23	0.84	43	0.84	63	0.8	83	0.84	103	0.67
4	0.8	24	0.78	44	0.94	64	0.84	84	0.88	104	0.9
5	1.08	25	0.84	45	0.8	65	0.84	85	1	105	0.84
6	0.84	26	0.74	46	0.84	66	0.84	86	0.9	106	0.78
7	0.74	27	0.69	47	0.84	67	0.84	87	0.9	107	0.76
8	0.8	28	0.69	48	0.9	68	0.8	88	0.9	108	0.72
9	0.98	29	0.69	49	0.84	69	0.84	89	0.9	109	0.67
10	0.84	30	0.78	50	0.69	70	0.84	90	0.84	110	0.94
11	0.74	31	0.78	51	0.84	71	0.94	91	0.84	111	0.84
12	0.84	32	0.78	52	0.8	72	0.84	92	0.84	112	0.78
13	0.78	33	0.9	53	0.85	73	0.9	93	0.84	113	0.76
14	1.17	34	0.84	54	0.75	74	0.84	94	0.74	114	0.72
15	0.8	35	0.78	55	0.84	75	0.84	95	0.74	115	0.67
16	0.69	36	0.69	56	0.74	76	0.9	96	0.74	116	0.94
17	0.98	37	0.78	57	0.74	77	0.69	97	0.74	117	0.84
18	0.72	38	0.88	58	0.9	78	0.84	98	1	118	0.78
19	0.78	39	1	59	0.74	79	0.84	99	0.84	119	0.76
20	0.69	40	0.88	60	0.74	80	0.84	100	0.88	120	0.72
										121	0.67

Comparison between proposed method and the previous ones

We were extracting the S-curve for cash flow of the stadium plan by using Milestone, BOQ, and the proposed method to compare them. The result is shown in Fig .2.

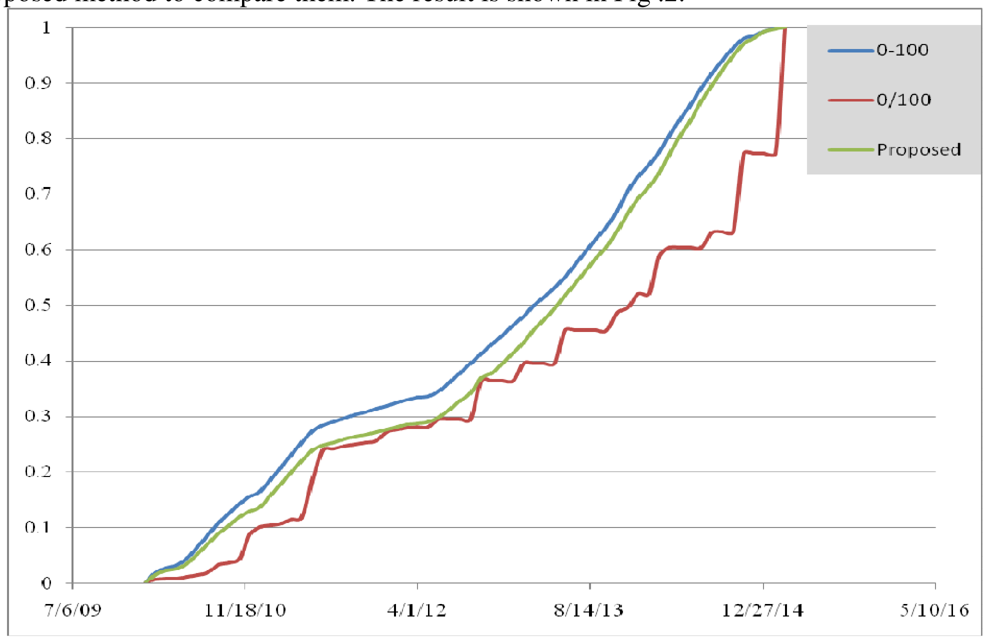

Fig .2. S-curves of milestone, BOQ and proposed method

Fig .2 shows that the proposed S-curve is being between the S-curves of two traditional methods. This clearly indicates the adjustment in proposed method but we were also demonstrating this adjustment mathematically. This demonstration has been constructed by using hypothesis analysis that is illustrated in Table 7.

Table 7
Hypothesis results

<table>
<tr><td colspan="3" rowspan="2">Statistical analysis</td><td colspan="2">Conclusion</td></tr>
<tr><td colspan="2">$\alpha = 0.05 \Rightarrow Z_{\alpha/2} = 1.96$</td></tr>
<tr><td rowspan="2">BOQ</td><td>Mean</td><td>339843828.6</td><td rowspan="2">BOQ vs. Proposed</td><td rowspan="2">$Z_{\alpha/2} > Z$</td></tr>
<tr><td>Variance</td><td>2.03602E+16</td></tr>
<tr><td rowspan="2">Proposed</td><td>Mean</td><td>339298650.7</td><td rowspan="2">Milestone vs. Proposed</td><td rowspan="2">$Z_{\alpha/2} > Z$</td></tr>
<tr><td>Variance</td><td>2.27465E+16</td></tr>
<tr><td rowspan="2">Milestone</td><td>Mean</td><td>202336231.5</td><td rowspan="2">BOQ vs. Milestone</td><td rowspan="2">$Z_{\alpha/2} < Z$</td></tr>
<tr><td>Variance</td><td>1.36928E+17</td></tr>
<tr><td rowspan="2">BOQ vs. Proposed</td><td colspan="2">S=1347086316408480</td><td rowspan="2">BOQ vs. Proposed</td><td rowspan="2">Null hypothesis is accepted</td></tr>
<tr><td colspan="2">Z = 0.0148539</td></tr>
<tr><td rowspan="2">Milestone vs. Proposed</td><td colspan="2">S=4989834077226910</td><td rowspan="2">Milestone vs. Proposed</td><td rowspan="2">Null hypothesis is accepted</td></tr>
<tr><td colspan="2">Z=1.9389131952459</td></tr>
<tr><td rowspan="2">BOQ vs. Milestone</td><td colspan="2">S=4915263365418740</td><td rowspan="2">BOQ vs. Milestone</td><td rowspan="2">Null hypothesis cannot accepted</td></tr>
<tr><td colspan="2">Z=1.96134185653075</td></tr>
</table>

Hypothesis analysis in Table 7 shows the significant difference between BOQ and Milestone methods and also the insignificant differences between the proposed method and any of the two traditional ones. So we can correctly use the proposed method instead of the BOQ and Milestone methods.

Conclusion

In this paper, we explained the usage of fuzzy AHP and fuzzy TOPSIS for weighting activities to achieve the correct progress as the relative subject to the project success. The proposed method can consider all of variables that may affect the project progress as qualitative and quantitative and the vagueness may be increased by human habits or type of projects, all together. Results show superiority of the proposed method in case of comprehensiveness and flexibility in comparison with other methods.

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