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Evaluation of Projects Performance by Using Value Engineering and Fuzzy TOPSIS

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ABSTRACT

One of the principal necessities of any organization is controlling the time and cost along with increasing the quality of their products. This strategy is always being considered in management challenges of project developments. A proven method for controlling and decreasing the costs in variety of projects, especially used in structural developments, is the value engineering.The decision theory which plays an important role in process of implementation programs of value engineering, utilizes the fuzzy theory in complicated and vague situations. For different aspects of decision making with inaccurate data sets, there are plenty of methods such as 'Fuzzy Multiple Attribute Decision Making' which could be applied in value engineering procedures. Structural building projects are good samples of inaccurate data sources with different mechanical, electrical, etc. parts.In current study, the fuzzy MADM approach of value engineering is applied to modernization of a school building. The fuzzy *AHP* is used to weight the evaluation metrics which are acquired from innovation step and fuzzy TOPSISis used to prioritize proposed schemes. Based on the estimation by value engineering team, the proposed method decreased the costs by 16.2% and saved the time by 26.42%, comparing with ordinary implementation scheme.
KEYWORDS: Functions, Value engineering, Cost, Value Index, Project operation criteria, Fuzzy multiple attribute decision making

1- INTRODUCTION

There are various methods of optimization schemes in developments and operations of projects which claim to lead success in project management challenges(Deweiri,Kaplan,2006). Along with technology growth and rectifications in project implementations, it is indispensable to take off classic management methods which are substituted by specialized modern tools and techniques. One of the pioneer methods in controlling the costs and operation quality is Value Engineering(Hamilton,2006). It analyzes the problem to separate functions that leads to better study of the whole system and utilizes group innovation techniques provides new management entries. The results of this method helps to increase product quality, decrease the losses and tries to find substitutions for cost saving strategies(Yang andHung,2007).

Current research is aimed to utilize value engineering with multi criterion fuzzy decision approach to investigate the improvement of project implementation. It is defined in Isfahan Modernization Institute and applied in mechanical equipment of *Hakim Farzanehschool.*

2-Value Engineering

Value Engineering in the literature of project management, time and quality are main metrics of project implementation (Deweiri andKaplan,2006).There are various methods in project implementation enhancements as project management topics. One of these tools in project management, especially in structural developments, is the value engineering. Based on engineering definition, value is the ratio of functionality to the costs i.e. lower costs or higher functionality lead to high amount of system "value". By this definition, it is possible to use value engineering in different phases of the project such as feasibility study, design, implementation and operations maintenance to enhance the implementation metrics of the original project. In value engineering the main concentration is on the functionality of the system. The value index for measurement of the user satisfaction is calculated as(Momeni,2006):

$$\text{Value Index} = \frac{\text{Functionality Price}}{\text{Functionality Cost}}$$

American Society of Value Engineering developed methodology for standardizing the six-stage model for value researches. Value engineering before presenting as a technique is based on a culture of professionalism. Creativity can not only be applied with law but also for the embedment of creativity real

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value of creativity as a cultural value should be identified. We can establish creativity with value engineering techniques (portal of management articles, 2011).

3-Fuzzy Analytical Hierarchy Process

Professor Thomas L. Sati, in 1970, has invented the Fuzzy Analytical Hierarchy Process. His method is a common and famous technique in the field of Fuzzy Multiple Attribute Decision Making. Laarhorren and Padrycz for the first method directly extended the Satie's method the fuzzy space. They established the judgment matrix using triangular numbers as different Judgments of experts.

4-Fuzzy TOPSIS Method

Then by the TOPSIS method is proposed in 1981 by Hwang& Yoon (Chen,2000). In this method, the importance coefficients of different indexes and the ranking of quality indexes and considered as variables verbal . These variables are being expressed as positive fuzzy numbers. The importance coefficients of each index could be reached by direct or indirect couple comparisons. It is offered to the decision makers to use verbalchoice ranking dialog variables(WangandLuo,2008).

To reduce the complexity of the decision matrix normalization in classic TOPSIS method, a linear transformation method is applied in order to unify the various index scales(Yang,Hung ,2007). The method of removing the scales, puts the fuzzy numbers in the range of [0,1]. So, we can propose an ideal solution of positive and negative as following(Jahanshahloo,Hosseinzadeh,2006)

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^-\right) \qquad , \tilde{v}_j^- = (1,1,1,), \ j = 1,2,..., \ m$$
$$A^+ = \left(\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_n^*\right), \ \tilde{v}_j^* = (0,0,0) \qquad , j = 1,2,...., \ m$$

5-METHODOLOGY

Current research is categorized in descriptive methods and is considered as a case study. This study is established based on the American Institute of Value engineering standards which is called the "Value Engineering Methodology."

6-Case Study

Current research is applied in mechanical constitutions of Hakim Farzanehschool.

7-Pre-study

In the first step of pre-study, through a meeting with employer, the requirements have been reviewed. Moreover, the mechanical constitutions of the school had some deficiencies and the critical states of the projects in these parts of the building. Saving the time spent on these parts could cause some progresses in the main general project.

The basic indexes in this context could be listed as bellow:

1) Feasibility of implementation: is an index of the proposal's implementation capability
2) Maintenance and fixing capability: measures how the proposal's scheme simplifies the maintenance functions during the operation period
3) Confidentiality: measures how the proposal's scheme provides the confidentiality in the system of study and reduces the possibility of fault occurrence and increases the safety of system.
4) Life time: measures how the proposal extends the durability of life time of the system and its subsets.

In order to weight the evaluation metrics of the previous step, the Hierarchical fuzzy Analysis Procedure is utilized in an Extension Analysis form. In order to collect the team's opinion on couple index comparison, the membership function of dialog variables is utilized and summarized in table 1:

Table 1.Membership function of index weighting dialog variables

From column to row				From row to column			
Equivalent fuzzy number			Linguistic variable	Equivalent fuzzy number			Linguistic variable
1	1	1	Same importance	1	1	1	Same importance
0.37	0.5	0.75	Similar or a little enhancement	1.33	2	2.67	Similar or a little enhancement
0.27	0.33	0.43	Little enhancement	2.33	3	3.67	Littleenhancement
0.21	0.25	0.3	Almost enhanced or much better	3.33	4	4.67	Almost enhanced or much better
0.18	0.2	0.23	Much more important	4.33	5	5.67	Much more important

The geometric mean of triangular fuzzy numbers table belonging to a member as a consequence of value engineering group decision opinions is calculated by using the following formula[2]:

$[\prod_{k=1}^{n} \tilde{a}_{ij}^{k}]^{\frac{1}{n}}$ i=1,2,3,... , m j= 1,2,3,…,m

In table 2, the comparison matrix of fuzzy coupled AHP is arranged. In the above table 1 the values bellow the main diagonal are calculated as the reciprocals of the values above the main diagonal.

Table 2. Matrix of paired index comparison

index	C1	C2	C3	C4
C1	(1.000 , 1.000 ,1.000)	ج(1.023 , 1.201 , 1.394)	(0.909 , 1.201 , 1.565)	(1.178 , 1.442 , 1.732)
C2	(0.717 , 0.833 , 0.977	(1.000 , 1.000 ,1.000)	(0.734 , 0.953 , 1.267)	(0.749 , 0.933 ,1.149)
C3	(0.639 , 0.833, 1.100)	(0.789 , 1.049 , 1.362)	(1.000 , 1.000 , 1.000)	(1.073 , 1.348 , 1.642)
C4	(0.577 , 0.693 , 0.849)	(0.870 , 1.072 , 1.335)	(0.609 , 0.742 , 0.932)	(1.000 , 1.000 , 1.000)

Using the EA method for each of the rows in the matrix of coupled comparison, the value of S_k, which is a triangle fuzzy number, is calculated using bellow expression:

$$S_k = \sum M_{kj} \times [\sum\sum M_{ij}]^{-1}$$

Where the K indicates the row number and i and j are the choices and indexes respectively.

S1 = (0.213 , 0.297 , 0.410)   S2 = (0.166 , 0.228 , 0.317)

S3 = (0.181 , 0.260 , 0.368)   S4 = (0.158 , 0. 215 , 0.297)

The magnitude rate of each S_k values is computed in relation with their other values. In the following, the magnitude rate of V is computed for each S_k:

V(S1≥S2)= 1.0000   V(S2≥S1)= 0.6007   V(S3≥S1)= 0.8045   V(S4≥S1)= 0.5055

V(S3≥S2)= 1.0000   V(S4≥S2)= 0.9096   V(S4≥S3)= 0.7224   V(s1≥s3)=1.0000

V(S2≥S3)=0.8121   V(S2≥S4)=1.0000   V(s1≥s4)=1.0000   V(S3≥S4)= 1.0000

Following equation is used to calculate the rational weight of each index in the coupled comparison matrices:

$$W`(C_i) = \min [V(S_i \geq S_k)]^T \quad k=1,2,3,\ldots,n \quad k \neq 1$$

The calculated values for W1 are:

$$W` = [\,1, 0.6007 , 0.5055 , 2.9108\,]^T$$

To normalize the mentioned equations, we can reach the weighting vector of each index:

$$W_j = W`(C_i) / \sum w`(c_i)$$

And the weighting vector for each evaluation index is calculated as:

$$W = [0.344 , 0.206 , 0.276 , 0.174]^T$$

Based on the statements from employer and the information collected throughout the project, the subject and borders of the value engineering study are determined(Yang and Hung ,2007). In this sub-step, the mechanical constitutions of the school building have been reviewed according to the employer's opinions. The subsystems of the mechanical constitutions are listed as bellow:

1) Sanitary sewer
2) Roof Flumes
3) Air conditioner channels
4) Heating channels
5) Cold-Hot water and gas piping
6) Valves and other sanitary equipment
7) Water coolers and ventilators
8) Complete powerhouse components

According to the total estimated cost of the project which is calculated in the information survey step, a preliminary basic cost of the each system is extracted based on the original scheme. Moreover, the critical trace time of each subsets of project is extracted in MSP software according to the school project scheduling. Based on the tables the curves from the software and considering the *Parto* theorem, 80% of the resources (i.e. the time and cost here) are spent on 20% of the task items(Gholipour andBeiraghi,2006). The subset of the heating system is chosen as the borders of the study.

8-Main Study Step

8-1-Information Sub-step

In this phase, a valuable component of the value engineering process is critical to project success. The information are analyzed and the garbage data are eliminated. These steps include setting goals, defining the functions, analytical methods, Argos system and FAST graph is costing and evaluation of performances. Completing the information stage as clearly and completely "accurate, defines the problem and illustrates the potential of the project goals (Richard, 2010).The heating constitutions of the school building are a centralized system companion with a transformer for end users. In the investigation of the basic plan, 17 parts are inspected as preliminary parts for heating system which are listed in table 3. In the rest, the cost and time of preparing and implementation of each part are being extracted based on current estimations.

8-2-Functionality Analysis Sub-step

The definition and analysis of the functionality is a principal in value engineering.‘Function’ can be defined, as the use demanded of a part of a product and the esteem value that it provides. Thesefunctions therefore make the product work effectively or contribute to the ‘salability’ of the product (HabibollahNajafi, Amir Abbas Yazdani, HosseinaliNahavandi, 2012). This step, inspires the most important difference of value engineering comparing with the other methods. In this step, the work papers with the same number and the same name of each part are delivered to team members and who were being asked to characterize the functionality of each member in the format of an “active verb” and a “measurable name” in the response of the question of “What is the task of that part?” and were being asked to write the result on the paper.In this step, totally 17 functions are determined for the heating system and its building parts. In the rest of this paper to determine the cost of each function, a function based analysis of costs is established based on cost-function model. In this method, to determine the prices, team members were being asked to divide the number 100 among the functions based on their functionalities. The average of assigned numbers by each member is specified as the price of that function. The value index is the indicator of function priorities for the rest of study, i.e. the creativity step(Karimi,2007). In table 3, the index value of each part in heating system is calculated.

Table 3.The calculation of cost and value index

The value index	Price (Rials)	The importance (%)	The importance percentage – team member opinions						Cost (%)	Cost (Rials)	functionality	No.
			6	5	4	3	2	1				
1.16	83579205.8	8.00%	9	15	6	3	7	8	31.93%	72043460	Fluid Transmission	1
4.65	48754536.7	4.67%	5	8	7	2	3	3	4.65%	10495800	Maintenance Capability	2
13.27	13929867.6	1.33%	1	2	1	1	1	2	0.47%	1050000	Fluid Filtering	3
4.52	27859735.3	2.67%	3	4	2	2	4	1	2.73%	6162000	Fluid Reservoir	4
3.64	66166871.2	6.33%	2	5	6	8	10	7	8.06%	181860000	Fluid Heating	5
5.96	50495770.1	4.83%	6	4	8	2	5	4	3.75%	8470000	Heat Generating	6
10.58	12188634.2	1.17%	1	1	1	1	2	1	0.51%	1152450	Pressure Control	7
19.64	12188634.2	1.17%	1	1	2	1	1	1	0.28%	620550	Temperature Control	8
5.58	461426865	44.17%	40	30	35	60	45	55	36.66%	82702060	Heat Transfer	9
31.34	47013303.2	4.50%	3	2	8	2	7	5	0.66%	1500000	Smoke Disposal	10
6.45	20894801.4	2.00%	1	2	4	2	2	1	1.44%	3240000	Pressure Producing	11
3.54	27859735.3	2.67%	4	5	1	2	3	1	3.49%	7872660	Pressure Maintenance	12
4.03	17412334.5	1.67%	1	3	1	1	3	1	1.91%	4320000	Torque Control	13
10.45	41789602.9	4.00%	10	4	3	3	2	2	1.77%	4000000	Waste Prevention	14
20.89	31342202.2	3.00%	6	3	4	1	1	3	0.66%	1500000	Sediment Prevention	15
23.68	12188634.2	1.17%	1	1	1	2	1	1	0.23%	514740	Fluid Ingress	16
26.34	47013303.2	4.50%	4	6	7	5	2	3	0.79%	1785000	Maintenance of Durability	17
-	1044740072	100%	-	-	-	-	-	-	100%	225614720	**Sum:**	

8-3-The Creativity Step

In this step, the functions are investigated according to their priorities and the suggestions to decrease the costs are offered. In this session, we attempted to obey the rules of mind storm technique which means that there was not any criticism to the suggestions from people(Jebelameli and et al, 2007).

Table 4.Scenarios from combination of suggestions

Proposals	Id	Scenarios
Using Plastic Foam Insulation	D1	**Proposals in s ubsets of scenario A1**
Supporting by two-side angles	D3	
Using plastic holders	D4	
Using 5-layer pipes in units	D6	
Using smoke disposal in cement materials	D8	
Using unit package system	D11	
Using independent taps in each unit	D14	
Using wall thermostat	D23	
Using plastic float taps	D28	
Using Plastic Foam Insulation	D1	**Proposals in subsets of scenario A2**
Supporting by two-side angles	D3	
Combination of risers	D5	
Using 5-layer pipes in units	D6	
Direct piping in basements	D7	
Using smoke disposal in cement materials	D8	
Using a bigger pot	D12	
Putting the riser taps in the walls	D13	
Using independent taps in each uni	D14	
Change in the decoration of power house	D16	
Using an expansion source	D21	
Displacement of expansion sources	D22	
Utilization of common filter	D24	
Using Plastic Foam Insulation	D1	**Proposals in subsets of scenario A3**
Supporting by two-side angles	D3	
Using plastic holders	D4	
Using 5-layer pipes in units	D6	
Using smoke disposal in cement materials	D8	
Using unit package system	D11	
Using independent taps in each unit	D14	
Using wall thermostat	D23	
Using plastic float taps	D28	
Using Plastic Foam Insulation	D1	**Proposals in subsets of scenario A4**
Supporting by two-side angles	D3	
Combination of risers	D5	
Using 5-layer pipes in units	D6	
Direct piping in basements	D7	
Using smoke disposal in cement materials	D8	
Using a bigger pot	D12	
Putting the riser taps in the walls	D13	
Using independent taps in each unit	D14	
Change in the decoration of power house	D16	
Using an expansion source	D21	
Displacement of expansion sources	D22	
Utilization of common filter	D24	
Using Plastic Foam Insulation	D1	**Proposals in subsets of scenario A5**
Supporting by two-side angles	D3	
Direct piping in basements	D7	
Using galvanized smoke disposal	D10	
Using a bigger pot	D12	
Putting the riser taps in the walls	D13	
Change in the decoration of power house	D16	
Floor heating system	D19	
Using an expansion source	D21	
Displacement of expansion sources	D22	
Using wall thermostat	D23	
Utilization of common filter	D24	

8-4-The Evaluation Step

In this step, the numerous ideas of the "Creativity" step are short listed towards the development step. In the first action, the primary and inaudible offers are omitted from the list. Finally, there remained last 27 offers which had inter-correlation among all of the proposals. According to this sort, 5 scenarios of A1 to A5 were formed from combination of these offers which are listed in table 4. In the following, the priority of each scenario of previous step with fuzzy TOPSIS is determined. We used dialog variable membership, which is indicated in table 5, to collect suggestions from team members about the importance of each scenario besides the specified index.

Table 5.The membership function of scenario ranking dialog variables

Equivalent fuzzy number	dialog variables
(0,0,1)	**Very Poor (VP)**
(0,1,3)	**Poor (P)**
(1,3,5)	**Medium Poor (MP)**
(3,5,7)	**Fair (F)**
(5,7,9)	**Medium Good (MG)**
(7,9,10)	**Good (G)**
(9,10,10)	**Very Good (VG)**

In Table 6, we mention the criteria for evaluating the proposals andthe obtained weights.

Table 6.Subject and weight for the choices evaluation criteria determined in the pre-study phase

	C1			C2			C3			C4		
A1	0.536	0.732	0.893	0.724	0.9	1	0.511	0.756	1	0.178	0.378	0.622
A2	0.679	0.893	1	0.552	0.74	0.9	0.422	0.667	0.91	0.489	0.8	1
A3	0.357	0.571	0.768	0.293	0.48	0.69	0.178	0.378	0.62	0.044	0.178	0.311
A4	0.143	0.304	0.464	0.224	0.41	0.62	0.378	0.622	0.82	0.156	0.356	0.533
A5	0.268	0.464	0.643	0.19	0.38	0.55	0.267	0.489	0.71	0.422	0.667	0.867

For this purpose some worksheets were put at the disposal of each member in the value engineering team and they were asked to specify their views concerning the importance of each choice (scenario) within each criterion by the above language variables.

In the rest, the arithmetic average of the fuzzy triangular numbers of each option's importance with each index is calculated using bellow formula(Jebelameli,Ghavamifar, Abaii,2007)

$$\tilde{X}_{ij} = 1/k[\tilde{x}_{ij}^{1}(+)\ \tilde{x}_{ij}^{2}\ (+)\ \ldots \tilde{x}_{ij}^{K}\ ]$$

The result for averaging views is phase decision matrix that has come in Table 7.

Table 7. Fuzzydecision matrix

	c1			c2			c3			c4		
A1	5	6.833	8.333	7	8.667	9.667	3.833	5.667	7.5	1.333	2.833	4.667
A2	6.333	8.333	9.333	5.333	7.167	8.667	3.167	5	6.833	3.667	6	7.5
A3	3.333	5.333	7.167	2.833	4.667	6.667	1.333	2.833	4.667	0.333	1.333	2.333
A4	1.333	2.8333	4.333	2.167	4	6	2.833	4.667	6.167	1.667	2.667	4
A5	2.5	4.333	6	1.833	3.667	5.333	2	3.667	5.333	3.167	5	6.5

$$\widetilde{\mathbf{R}} = [\widetilde{r_{ij}}]_{mn}; \qquad \widetilde{r_{ij}} = \left(\frac{a_{ij}}{C_j^*}, \frac{b_{ij}}{C_j^*}, \frac{C_{ij}}{C_j^*}\right)$$

$$C_j^* = max\ C_{ij}$$

$$\widetilde{x_{ij}} = (a_{ij}, b_{ij}, C_{ij})$$

Table 8 indicates phase normalized decision matrix.

Table 8. Fuzzy rectified decision matrix

Weight	Criteria	Index
0.334	Feasibility of implementation	C1
0.206	Maintenance and fixing capability	C2
0.274	Confidentiality	C3
0.174	Life time	C4

By averaging the suggestions, the fuzzy decision matrix is (D) which is indicated in table 6. In the following, the rectified fuzzymatrix (R) is calculated. By multiplying this matrix by weight vector of indices acquired from fuzzy AHP, the weighted rectified fuzzy (V) is calculated in table9.

Table 9. The weighted rectified fuzzy

	C1			C2			C3			C4		
A1	0.179	0.245	0.298	0.149	0.185	0.206	0.141	0.209	0.276	0.031	0.066	0.108
A2	0.227	0.298	0.334	0.114	0.153	0.185	0.117	0.184	0.251	0.085	0.139	0.174
A3	0.119	0.191	0.256	0.060	0.099	0.142	0.049	0.104	0.172	0.008	0.031	0.054
A4	0.048	0.101	0.155	0.046	0.085	0.128	0.104	0.172	0.227	0.027	0.062	0.093
A5	0.089	0. 155	0.215	0.039	0.078	0.114	0.074	0.135	0.196	0.073	0.116	0.151

The elements of weighted rectified matrix are triangular fuzzy numbers in the range of [0,1]. By this, we can establish the ideal solution of positive and negatives in the following definition:

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\right) \quad , \tilde{v}_j^- = (1,1,1,), \; j = 1,2,\ldots, \; m$$
$$A^+ = \left(\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*\right), \; \tilde{v}_j^* = (0,0,0) \quad , \; j = 1,2,\ldots, \; m$$

In the other hand, all positive ideal triangular fuzzy number (1,1,1) and all negative ideal solutions (0,0,0) are already considered. So, the summation of distances of each option in ideal positive solution and ideal negative solutions (d_1^-, d_1^+) are calculated. The rational neighborhood index (CC_I) for each option is also calculated in following where the priority of choices is determined according to the descending order of rational neighborhood index. In table 10, the rational indices and the priority of each option (scenario) are indicated based on this index.

Table 10. The neighborhood rational index and option ranks with fuzzy TOPSIS method

option	Rational neighborhood index(cci)	rank
A1	0.178363	2
A2	**0.192022**	1
A3	0.113706	4
A4	0.110209	5
A5	0.125472	3

As a result, based on tables above, the scenario A2 is considered as value engineering team's proposal for the heating system of school building.

8-5-The expansion Sub-step

In the expansion phase, the best idea is selected from the evaluation step and is being extended in order to prepare the final suggestions. In current research, the value engineering team has extended the selected scenario in the previous step. The costs and suggested time (scenario A2) are estimated and were being compared with suggested proposal.

8-6-Presentation Sub-step

In the end of study phase, the proposed scheme of value engineering companion with plans, technical specifications and results of studying the value engineering and estimating the costs and time is presented to the employer of the project. In this session, a documented report of activities of value engineering team, which is a summarized version of current report, is delivered to the employer. We should also mention that the proposed method of value engineering team has been accepted by the employer and project consultants and is transferred to implementation phase.

9-Conclusion

The cost, time and quality are main operational criteria in project operations (Jahanshahlooand et al,2008).In current research, based on the estimation accomplished by value engineering team, by applying the proposed scheme, project implementation costshas been reduced by 16.3% of the original scheme. The time spent on the project also is estimated to be reduced by 26.42% of the original plan. Based on these results, the overall cost would be reduced by 6.8% and the critical path of the project is enhanced by 9.8%.

So, we can claim that utilization of the value engineering with current approach could enhance the project implementations.

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