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Developing a model for identifying successful petrochemical projects based on Multiple Criteria Decision-Making approach

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Abstract. Success of a project and its assessment is an issue regarding which many studies have been carried out, though there is no significant consensus about the issue. Many of success factors are of a mental nature and are different from viewpoints of persons involved in the project. This issue has caused led to various viewpoints on success criteria based on identity of assessor and studied projects. The present article reviews existing viewpoints on success factors through studying theoretical principles and a model has been developed to identify successful petrochemical projects according to Multiple Criteria Decision-Making (MCDM) approach and the employer's attitude through combining success factors gained from theoretical principles and criteria gained from interviewing industrial experts. The first section of the article reviews theoretical principles regarding the project success. In the second section, the techniques used to identify importance of criteria and assess projects based on the mentioned criteria have been studied. The third section explains the methodology to extract criteria's importance coefficients and assessing options based on the coefficients using a numerical sample. Finally, the fourth section has been allocated to conclusions.

Keywords: Fuzzy logic, project success, multiple criteria decision-making, TOPSIS, fuzzy hierarchical analysis

1. Introduction

Although nowadays projects are carried out in various scales and kinds and there is a better understanding of project management and tools, and beyond all, behavioral and organizational aspects in projects have been gained, but there is still little emphasis on the concept of success. Some people even doubt that project success factors are identified and organized during project planning. In the past, the ground rules of "on time", "based on budget", and in higher levels "based on commitments" were known as the success factors. However, project management includes many examples regarding projects which have been completed later than planned or at higher costs, but they have been said to be successful. There are also projects which have been completed according to timetable and budget plan, but they have been said to be examples for incapability (Square, 2000). It is certain that examples which are related to being on time, based on budget and even based on commitments are not just the satisfactory criteria for success. The reality is that the concept of success, especially project success, is a complicated issue. A brief study on different references of project management shows different viewpoints and non-consensus about the definition of "project success."

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Studies by McCoy (1986) indicate that not only a standardized definition of project success has been offered, but also there is no accepted method for measuring success. Similarly, Wells (1998) has voiced concern over the lack of a definition for success, though a general definition exists. According to Liu and Walker (1998), project success is an issue which has been studied numerously, but has been agreed on rarely. The concept of project success has been offered as vague and multidimensional definitions, because the project success can have different definitions based on the number of persons involved in the project, and their different points of view, and this issue leads to lack of consensus on identifying projects as successful. Kerzner (1989) said that by the early 1980s, the project success was referred to as completing a project within the preset timetable, budget plan and quality objectives. The same belief still is minds that success is the timely completion of a project within the budget plan meeting all the required specifications.

2. Extracting success factors

After extracting the project's success factors from theoretical principles and adding them up, the resulted factors were presented in the frame of a questionnaire to a group of university professors and petrochemical experts in order to collect their viewpoints and information on other factors which may be effective on the project success process. Summarized results led to extracting 27 success factors which were referred to the petrochemical experts in the frame of questionnaires as the success factors of petrochemical projects. In this phase, 26 persons, including petrochemical experts, project managers and engineers filled out the questionnaires based on the Likert scale. After defining Chronbach Alpha (0.8847), the questionnaires were analyzed using Binomial and Kendal tests and 6 factors were extracted as the main success factors which have been shown in the table 1.

3. Fuzzy AHP method

An appropriate decision-making model needs vagueness and ambiguity, because fuzziness and vagueness are the common specifications in many decision-making issues (Yu, 2002). Since decision-makers offer uncertain and approximate responses instead of exact quantitative responses, changing qualitative preferences to point estimates may not be an appropriate approach. So, using the common AHP which needs exact selection of figures in pair wise comparisons will not be sufficient and the uncertainty should be considered in pair wise comparisons (Yu, 2002). Since linguistic fuzzy variables take both optimistic and pessimistic viewpoints of the decision-makers into account, the linguistic figures, which their membership functions are specified by triangular membership functions and in some cases by trapezoidal functions, are used to assess ranking of the preferences (Liang & Wang, 1994). Therefore, it is clear that the fuzzy AHP is more appropriate and more effective than the common AHP.

Decision-makers have found that it is more reliable that to decide according to distance-based judgments instead of fixed numerical figures, because due to the fuzzy nature of comparison processes, they are unable to explicitly describe their preferences. In 1983, two Dutch researchers named Van Laarhoven and Pedrycz introduced a method for the analysis of hierarchical process which was based on the least logarithm squares.

Complicated arithmetical and mathematical calculations of the method caused it not to be used widely. In 1996, another method named Extension Analysis was proposed by a Chinese researcher named Chang which is known as the Laarhoven and Pedrycz extension method. Numbers used in this method are fuzzy triangular numbers. Due to the fact that no fuzzy triangular figure has been set in advance for the most optimistic, the most probable, and the most pessimistic cases (the experts are free to select every number within 1/9 to 9 range) and the simplicity of the method, we use the Chang extension analysis method from among the fuzzy AHP methods (many studies have been conducted on AHP and fuzzy sets, which exist in different sources. So, we will not describe them). The Chang extension analysis steps are as follow:

- Step 1: The fuzzy combined value for the i^{th} entity is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, calculate the fuzzy sum of m extension analysis values for a special matrix, so that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j , \sum_{j=1}^{m} m_j , \sum_{j=1}^{m} u_j \right)$$

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, calculate the fuzzy sum of m extension analysis values for a special matrix, so that:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i , \sum_{i=1}^{n} m_i , \sum_{i=1}^{n} u_i \right)$$

In the next stage, the reverse vector is calculated as:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i} , \frac{1}{\sum_{i=1}^{n} m_i} , \frac{1}{\sum_{i=1}^{n} l_i} \right)$$

- Step 2: The possibility degree $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$$V(M_1 \geq M_2) = \sup[\min(\mu_{M_1}(x), \mu_{M_2}(y))]$$

This can be calculated as follows:

$$V(M_1 \geq M_2) = hgt\,(M_1 \cap M_2) = \mu_{M_1}(d)$$

$$= \begin{cases} 1 & if \quad m_1 \geq m_2 \\ 0 & if \quad l_2 \geq u_1 \\ \dfrac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)} & otherwise \end{cases}$$

In which d is the maximum common space D between μ_{M_1} and μ_{M_2} (see figure 1).

- Step 3: The possibility degree for a convex fuzzy number compared to other convex fuzzy numbers $M_i \ (i = 1, 2, \dots, k)$ is defined as:

$$V(M \geq M_1, M_1, \dots, M_k) = V\,[(M \geq M_1) \ and \ (M \geq M_2) \ and \dots and \ (M \geq M_k)],$$
$$= \min V(M \geq M_i), \quad (i = 1, 2, \dots, k)$$

Suppose that for $i = 1, 2, \dots, k \,;\, k \neq i$ we have $d'(A_i) = \min V(S_i \geq S_k)$ so, the weight factor is defined based on the following formula:

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T$$

In which $A_i \ (i = 1, 2, \dots, n)$ are n factors.

- Step 4: Using normalization, the normalized weight vector is:

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T$$

4. TOPSIS method

The present article offers the combined method of AHP and TOPSIS for assessing finished petrochemical projects. The TOPSIS method considers MADM problems which have m options as a geometric system with m points in an n-dimension space of factors. This method is based on the concept that the selected option should be at the least distance from the ideal positive solution and at the most distance from the ideal negative solution. TOPSIS has defined an index as nearness to the ideal positive solution and remoteness from the ideal negative solution. Then it selects the option with the most similarity to the ideal positive solution (Hwang and Yoon, 1981), (Wang and Chang, 2007) .It is often hard for a decision-maker to give an exact score to an option at a certain criterion. The strong point of the fuzzy approach is to allocate relative importance to criteria using fuzzy numbers for creating proportion with the real world. Selecting the best option using the TOPSIS method requires taking the following steps:

- Step 1: The normalized decision matrix should be normalized using Euclidean method (norm).

$$n_{ij} = \frac{r_{ij}}{(\sum_{i=1}^{m} r_{ij}^{2})^{\frac{1}{2}}} \quad , \quad (i = 1, \dots, m), (j = 1, \dots, n)$$

- Step 2: Set up V the Weighted Normalized Decision Matrix. Elements of the Weighted Normalized Decision Matrix V_{ij} are calculated based on the following formula:

$$v_{ij} = w_j n_{ij} \quad , \quad (i = 1, \dots, m), (j = 1, \dots, n)$$

In which w_j is the weight of the j^{th} criterion or index and $\sum_{j=1}^{n} w = 1$.

- Step 3: Determine the ideal positive and negative solutions.

$$A^+ = \{v_1^+, ..., v_n^+\} = \{(\max_j v_{ij} | i \in I), (\min_j v_{ij} | i \in J), i = 1,2,...,n\}$$
$$A^- = \{v_1^-, ..., v_n^-\} = \{(\min_j v_{ij} | i \in I), (\max_j v_{ij} | i \in J), i = 1,2,...,n\}$$

- Step 4: Calculate remoteness of each option from the ideal positive and negative solutions using n-dimensional Euclidean distance.

$$d_i^+ = \left\{ \sum_{j=1}^{n} \left(v_{ij} - v_j^+ \right)^2 \right\}^{\frac{1}{2}} \quad , \quad d_i^- = \left\{ \sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2 \right\}^{\frac{1}{2}} \quad , \quad (i = 1,2,\ldots,m)$$

- Step 5: Estimate relative nearness to the ideal solution. The relative nearness of A^i to A^+ has been defined as:

$$C_i = d_i^- / (d_i^- + d_i^+) \quad , \quad (i = 1,2, \ldots, n)$$

- Step 6: Use descending order of options to rank them.

5. Modeling using real data

In this section, coefficients of the main criteria of success are calculated using definitions and concepts offered in relation with the EA method. After filling out the second questionnaire by 14 project managers at petrochemical complexes, we used geometric mean to combine pair wise comparison matrixes, based on which the final pair wise comparison matrix is seen in table 1:

Table 1: final pair wise comparison matrix for main project success criteria

Criteria	Compliance with pre-set budget	Compliance with timetable	Compliance with quantity and quality specifications	Employer's satisfaction from project	Expected application of project	Appropriate capital return
Compliance with pre-set budget	(1,1,1)	(0.348,0.57,1.175)	(0.196,0.239,0.389)	(0.302,0.429,0.991)	(0.171,0.213,0.374)	(0.247,0.347,0.725)
Compliance with timetable	(0.851,1.753,2.872)	(1,1,1)	(0.248,0.354,0.523)	(0.461,0.724,1.426)	(0.225,0.306,0.414)	(0.319,0.45,0.851)
Compliance with quantity and quality specifications	(2.574,4.184,5.09)	(1.913,2.826,4.028)	(1,1,1)	(1.213,2.015,2.879)	(0.467,0.639,1.17)	(0.93,1.495,2.060)
Employer's satisfaction from project	(1.01,2.331,3.315)	(0.701,1.381,2.172)	(0.347,0.496,0.824)	(1,1,1)	(0.324,0.523,0.837)	(0.569,0.883,1.389)
Expected application of project	(2.672,4.692,5.853)	(2.416,3.264,4.454)	(0.855,1.564,2.143)	(1.194,1.911,3.084)	(1,1,1)	(1.026,1.786,2.396)
Appropriate capital return	(1.379,2.885,4.042)	(1.175,2.223,3.134)	(0.485,0.669,1.758)	(0.72,1.132,1.758)	(0.417,0.560,0.975)	(1,1,1)

So, S_i values are calculated as:

S_1 =(0.033,0.057,0.147) S_2 ==(0.045,0.094,0.223) S_3 =(0.117,0.249,0.511)
S_4 =(0.057,0.135,0.3) S_5 =(0.133,0.291,0.596) S_6=(0.075,0.173,0.399)

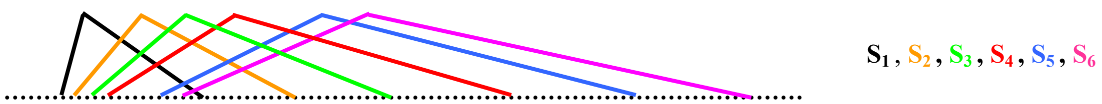

Fig. 1: Comparing fuzzy triangular numbers

In which the below numbers show non-normalized weights of the first to sixth indices of the table, i.e.:

$$W' = (0.056, 0.315, 0.9, 0.519, 0.1, 0.694)$$

The normalized weight vector is:

$$W = (0.016, 0.315, 0.258, 0.149, 0.287, 0.199)$$

So, expected application of project, compliance with quantity and quality specifications, appropriate capital return, employer's satisfaction, compliance with timetable, and compliance with pre-set budget are respectively the most effective success factors in petrochemical projects.

6. Using TOPSIS in prioritizing projects

Assessing four projects based on main success criteria led to setting up 14 decision matrixes. Before using the geometric mean method to combine data with each other, determination of fuzzy triangular numbers was carried out based on the Minkovski method. Then, the determined data were combined and the final matrix was extracted for final ranking of the projects:

Table 2: TOPSIS method's final decision matrix

	Compliance with pre-set budget	Compliance with timetable	Compliance with quantity and quality specifications	Employer's satisfaction from project	Expected application of project	Appropriate capital return
A	4.132	4.095	4.461	4.309	4.882	5.056
B	3.469	5.506	4.132	3.927	5.164	4.395
C	6.179	6.122	6.845	6.298	6.852	7.752
D	5.591	6.217	6.052	5.672	5.928	6.093

The more the option is closer to the ideal solution (A_i^+), the more C_i^+ value will be closer to one, so the studied projects will be ranked as follows based on descending C_i^+ order:

4	3	2	1
A	B	D	C
0.1559	0.2854	.7855	0.9770

Therefore, the C project was introduced the most successful project and the A the least successful project.

7. Conclusion:

The study aims to design a model for identifying successful petrochemical projects. Considering its nature and considering all factors effective in successful implementation of projects, especially contradictory factors, and including qualitative criteria in assessment and using viewpoints of experts regarding comparison of criteria, global models to identify successful petrochemical project is to combine the fuzzy AHP and TOPSIS. Extracted weights for main criteria have been derived using the FAHP technique and in the next stage TOPSIS has been used to assess projects. Meanwhile, from among 27 criteria extracted from theoretical bases and interviewing experts, the expected application, compliance with technical and qualitative specifications, capital return rate, employer's satisfaction, compliance with timetable, compliance with preset budget were named the most effective criteria of success for petrochemical projects.

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