Evaluation of Construction Projects Using Fuzzy TOPSIS Method

D. Darvishi Salookolaei[*,1] , M. Mohamadi Nasab[2]

1- Department of Mathematics, Payame Noor University, Tehran, Iran.
2- Post-graduate student of Civil Engineering, Maziar University, Ruyan, Iran.

Abstract - The purpose of this study was to evaluate cost and time reduction strategies in construction projects using fuzzy TOPSIS method. The information required for the research was obtained by a questionnaire. The target population was engineers working on construction projects, other managers and officials who were selected using a combination of both targeted non-probability and judgmental snowball sampling. In the first stage, the sample size consisted of 108 community members who were available to evaluate the importance and status of the variables in the construction projects and in the second stage, according to the selection of 10 experts from the 108 respondents who were selected. In terms of experience and competency, the research subjects had higher priority than others to evaluate and rank the projects. This research was a developmental-applied research and a survey method. The results of the data analysis showed that Tajrish hospital had the highest weight of 0.3935, as the operating conditions were better than other projects and experts confirmed this. Subjects have been obtained as well as the ideal positive distance and the negative ideal distance for each of the options. According to the experts, identified factors have great effects on reducing the time and cost of construction projects. It is suggested to implement them in different organizations and projects in terms of type of activity in order to control the time and cost in any project.

Keywords: Construction Projects, Cost, Evaluation, Fuzzy Topsis, Ranking.

1. Introduction

One of the main issues that communities are involved in is construction. infrastructure and national projects play an important role in achieving the construction by the communities, so the delay in exploiting infrastructure projects is equal to the delay in the development of the country and there are several consequences such as: increasing project cost, stagnation of capital, loss of materiality, decreasing power of project budget, decreasing quality of public dissatisfaction (Bayat & Taherkhani, 2016). In terms of scientific status, value and according to the attributes of project management and affecting factors on the projects success, acheiving the time goals is one of the most important indicators of success. So far, various studies have been carried out on delays, some of which have attempted to convert project delays into small quantities and have investigated this issue using various methods (Nazarpour and Taheri Amiri, 2016). In fact, project delaycan be caused by many factors, many of which can be controlled using proper management. There are several tools for proper planning of projects, each of them is used at project control and management level to improve project scheduling performance. Although many efforts and studies have been carried out to control project delays, it seems that the main problem of project delays is not primarily related to the nature of the project and is related to the project management-level planning. In fact, if there is a proper decision-making model for controlling a set of projects, delays can largely be controlled (Cheraghi et al., 2017). In fact, contractors of construction project often focus on starting a project, but gradually they overlook the importance of the final stages of the project and are unable to complete the project with predetermined success criteria. At first, they are like the commanders who won the conquered city gate, but close to the exit gates toward the new horizons like the one who takes the sleeping drug, slipping and stumbling. Typically, in the process of implementing two-level construction plans, some efforts are carried out to complete the activities on the one hand and maintain the quality of plan until the finishing project at a reasonable speed and pace (if no events that cause the activities to be completely stopped). Ideally, the time and budget required to complete the project when reaches the final stages of the project's operations will reach its final stages, but in reality and in practice we will see the project go into a red zone and some costly problems and factors are created at work before reaching the endpoint (Chopman, 2015). In recent years, due to the high profitability of the construction industry, much of the country's capital has moved into the industry and with the entry of unskilled and purely capitalist individuals, the cost of building residential buildings has been increased. Also, without observing the value engineering in designing and technical calculations, a large amount of steel and concrete is buried underneath other building materials and this became the buildings heavier and other consequences. Also, after importing semi-luxurious and luxurious materials from other countries, especially China and competition in using these types of materials due to their cheapness, the finished cost of per square meter of residential buildings has been increased and this affects domestic industry. Also, gap between the purchasing power and the price of supply has decreased peoples' ability, and in recent years this capital market in Iran has suffered a prolonged stagnation. While, a boundary can be created between luxury homes and residential homes by standardizing the residential buildings and this avoids costly situation for someone who looking for shelter for themselves and their families. This is possible using the engineering system to create an appropriate culture and avoid luxury and proper use of materials and design of residential structures. Given the stagnation in the housing market, it is a good opportunity for builders to pay more attention to saving the industry in order to prevent price increases and to build and implement customized patterns to suit consumers' needs and capabilities (Sedighi, 2016).

This paper examines the importance and status of research variables in construction projects and also, through the fuzzy TOPSIS process, a few examples of projects were ranked against the influential variables in reducing the cost and time of construction projects. In fact, this paper examines the causes and factors of this problem and appropriate solutions to reduce the time and cost of construction projects using fuzzy TOPSIS method.

2. A Review On the Theoretical Foundations and Research Background

Veron et al. (2018) conducted a study called Evaluation and Initial Construction Costs and Time Risk Assessment and Evaluation of Large-Scale Construction Projects in Singapore. Their results showed that the proposed workflow can estimate the cost of construction and time well at the 2% confidence level. The Dial-a-Truck simulation results of two other projects, which are in the early stages of planning, have been compared with Project A to evaluate the accuracy of cost and time. The results show that the proposed workflow as a predictor is a valuable tool in estimating construction costs and time for large scale projects, especially for feasibility studies. Elamou & Elaw (2017) in their research entitled Are Longer Projects More Deviating than Short Construction Projects? The purpose of this article is to analyze two specific types of construction projects (roads and buildings) and to test if there is a correlation between cost performance and construction time. In fact, the results showed that longer projects do not necessarily have higher cost deviations. Unlike building construction, road construction showed a negative correlation between cost and construction time. However, some longer projects showed relatively high cost deviation than the smaller ones. On the other hand, Donyaa Mehran (2016) conducted a study on the adoption of building information modeling in the UAE construction industry for advanced electronics companies. The research results indicate three major barriers to Building information modeling: lack of building information modeling standards, lack of awareness about Building information modeling, and resistance to change; a combination of past and current studies on Building information modeling implementation and future research directions is presented. Gholami and Aminian (2015) also carried out a research on identifying and analyzing the causes of cost increases and delays in construction projects using the hierarchical analysis process as case study of the project of alignment and refurbishment of the Pol-e-Sefid-Qaemshahr bridge.

An overview of the causes showed that the two main causes of delay and increase in cost of road construction projects include: financing and payment of work done, weather conditions, delay in payment process by employer, unforeseen conditions of land and lack of construction materials in Market - Although they make up about 99 percent of the factors, they create about a 25 percent delay. In another study, Gholami and Rayan Poor (2015) conducted a study to investigate the factors affecting delay and increase costs in road projects by paired comparison and hierarchical analysis. The results showed that the first two factors, while accounting for about 11% of the factors that cause delays and increase costs, account for about 32% of the delays that indicate the high impact of these factors. There are also 5 major factors causes delays that counted for 32 percent delays and increase costs in road construction projects. Therefore, increasing costs and the overall project delay can be reduced in the road construction projects by reviewing several factors causing delay. Based on previous research, it has been shown that the cost reduction and time of construction projects is affected by several factors, meaning that there must be some factors to make the projects.

3. Research Methodology

The present study is applied-developmental in term of target and nature using survey method. The information required for the research was obtained by a questionnaire. The target population was engineers working on construction projects and other managers and officials who were selected using a combination of both targeted non-probability and judgmental snowball sampling. Since, the experts should have sufficient competency to be active and effective, out of 128 quesionnairees, 108 accepted questionnaires (familiar with the issue andhaving working history more than five years) have been selected. At first, the sample volume consisted of 108 subjects of the society to evaluate the importance and status of the factors in the construction projects and in the second stage, 10 experts from the 108 respondents were selected who had higher experience and aristocracy and higher priority than others to evaluate and rank the projects. After validation of this questionnaire by 7 professors, reliability of questionnaires was estimated using Cronbach's alpha coefficient above 0.7. In this study, data were analyzed using fuzzy TOPSIS method and data were analyzed by MATLAB software. The following table summarizes the demographic of the research sample.

Table 1: Summary of the demographic description of the research sample

Row	Kind of Characteristic	Characteristic	Relative Frequency (Percent)	Number
1	Gender	Male	94	101
		Femal	6	7
2	Education Degree	B.A.	22	24
		M.A.	68	73
		Ph.D.	10	11
3	Working History	5 to 10 years	18	19
		10 to 20 years	56	61
		More than 20 years	26	28

According to the descriptive analysis of the findings from Table 1, out of 108 sample of engineers working in construction project and civil engineering projects and other managers and authorities in term of education level, 22% of experts had bachelor's degree, 68% had master's degree and 10% had Ph.D. degree. According to work experience, the highest percentage of experts had a job experience between 10 and 20 years with 56% and the lowest percentage had a job experience of 5-10 years with 18%. Finally, in term of gender, the highest percentage; i.e. 94% of experts was male and the lowest percentage; i.e. 6% was female.

4. Statistical Analysis:

The mean of the research data was used to describe the data. A summary of the descriptive statistics on the status and importance of the research variables is given in the following Tables.

Table 2: Descriptive information about the status of the research variables

Research variables	Weighted Average	Number of Research Criteria	Number of Data	Maximum	Minimum
Financial Effects	5.43	9	108	7	3
Planning	5.445	9	108	7	3
Mental & Psychological	5.402	8	108	7	3
Environment	5.405	12	108	7	3
Contractor	5.42	18	108	7	3
Consultant	5.441	18	108	7	3
Client	5.41	17	108	7	3

Table 3: Descriptive information about the importance of the research variables

Research variables	Weighted Average	Number of Research Criteria	Number of Data	Maximum	Minimum
Financial Effects	5.642	9	108	7	3
Planning	5.663	9	108	7	3
Mental & Psychological	5.666	8	108	7	3
Environment	5.61	12	108	7	3
Contractor	5.65	18	108	7	3
Consultant	5.647	18	108	7	3
Client	5.664	17	108	7	3

As can be seen, based on the views and professional experience of experts in the field of construction and civil engineering at seven-degree spectrum , the weighted average importance of the "financial effects" variable was 5.642 and the weighted average importance of the "planning" variable was 5.663 and the weighted average importance of "mental and psychological" variable was equal to 5.666 and the weighted average importance of "environmental" variable was equal to 5.61 and the weighted average importance "contractor" variable was equal to 5.65 and the weighted average importance of "consultant" variable was equal to 5.647 and the weighted average importance of "employer" variable is calculated as 5.664%, while the weighted average status of "financial effects" was equal to 5.43" and weighted average status of "planning" equal 5.45 and weighted average status of "mental and psychological" was 5.402 and weighted average status of "environmental" was equal to 5.405. weighted average status of contractor was 5.42 and the weighted average status of the consultant was 5.441 and the weighted average status of employer was 5.41%. Further analysis of the descriptive statistics of the research data can be found in the tables above.

5. Ranking Research Criteria Using Fuzzy TOPSIS:

The TOPSIS model and the fuzzy TOPSIS model are used to rank the options derived from multi-criteria decision making (when the number of options is greater than 1, they are ranked using these methods). The difference between fuzzy TOPSIS and TOPSIS is that fuzzy TOPSIS uses fuzzy and uncertain property to rank the options. In other words, fuzzy TOPSIS uses continuous values and TOPSIS uses discrete values. So discrete data can be counted, but continuous data can be measured. Discrete data can only be assigned to certain values. Continuous data can be measured and declared in numbers.

In order to compute the TOPSIS technique first, a linguistic spectrum should be used for data collection. Chen (2000) proposes a seven-point linguistic scale for scoring each option based on each criterion. The decision matrix can also be used to rate the importance of criteria by techniques such as ANP, so Chen has proposed a similar range for rating criteria. The nine-degree Likert spectrum is commonly used in the qualitative evaluation of options in TOPSIS techniques with definite numbers. In the qualitative evaluation of options in the fuzzy TOPSIS technique, a seven-degree scale is commonly used. Chen's proposed seven-degree spectrum in evaluating options for fuzzy TOPSIS technique is as follows:

Table 4: Triangular fuzzy numbers equivalent to 7-degree spectrum to evaluate options

Linguistic variable	Fuzzy equivalent
Very poor	(0, 0, 1)
Poor	(0, 1, 3)
Medium poor	(1, 3, 5)
Fair	(3, 5, 7)
Medium good	(5, 7, 9)
Good	(7, 9, 10)
Very good	(9, 10, 10)

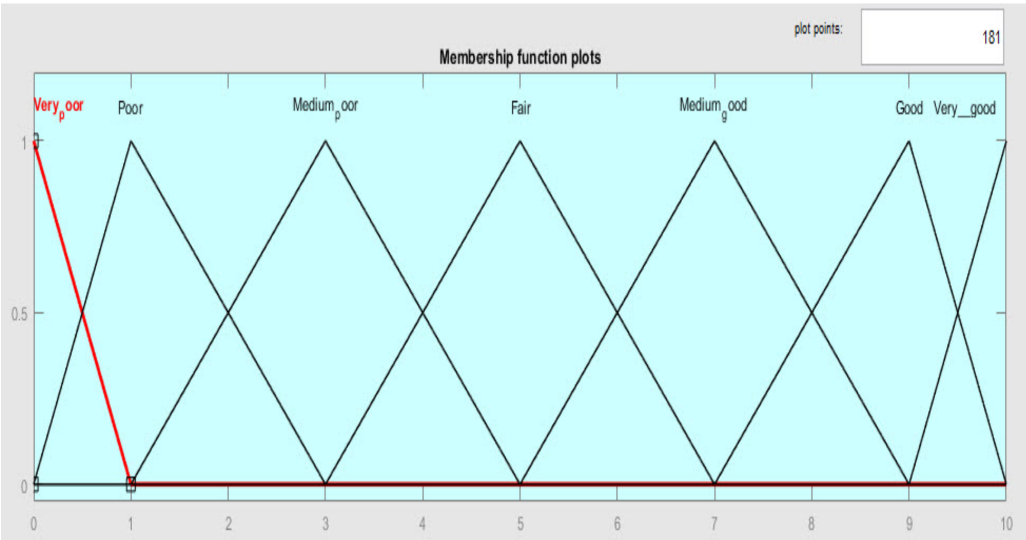

Figure 1: Triangular Fuzzy Numbers Equivalent to 7 Degree Spectrum to Evaluate Options

6. Fuzzy TOPSIS algorithm Solution:

Create a decision matrix for ranking including *m* options and *n* criteria: Table 5 presents the decision matrix. As can be seen, the relative importance of the options to each criterion is specified by triangular fuzzy numbers. Given that 10 experienced and accessible experts have been interviewed, all linguistic expressions must first be transformed into triangular fuzzy numbers and considered by experts as the evaluation criteria that will ultimately be the decision matrix as triangular fuzzy numbers as shown in the Table 5 and 6.

Table 5- Decision Matrix

Decision Matrix	Mental & Psychological	Environment	Employee	Contractor	Financial Effects	Consultor	Planning
Reconstruction of Marivan after the war	9,10,10	3,5,7	1,3,5	1,3,5	3,5,7	1,3,5	7,9,10
Betty Residential Complex at Third Phase of Andishe	3,5,7	7,9,10	3,5,7	3,5,7	7,9,10	1,3,5	5,7,9
Tajrish 600 hospital-bed	5,7,9	7,9,10	5,7,9	7,9,10	5,7,9	7,9,10	1,3,5
Zahedan Dental School	5,7,9	3,5,7	1,3,5	1,3,5	3,5,7	1,3,5	7,9,10
Minab Sports Stadium	3,5,7	7,9,10	3,5,7	3,5,7	7,9,10	1,3,5	5,7,9
Sanandaj Tourism Hotel	7,9,10	7,9,10	5,7,9	7,9,10	5,7,9	7,9,10	1,3,5
Sanandaj and Marivan Water Supply Network Reform Project	1,3,5,7	5,7,9	3,5,7	9,10,10	1,3,5	5,7,9	3,5,7

Table 6: Calculate the proximity factor of each option

Option	Normalized CCI	CCI	Negative Ideal Distance	Positive Ideal Distance	Ranking
Reconstruction of Marivan after the war	0.2699	0.4286	0.5700	0.7598	4
Betty Residential Complex at Third Phase of Andishe	0.3366	0.5345	0.7054	0.6144	2
Tajrish 600 hospital-bed	0.3935	0.6249	0.8274	0.4967	1
Zahedan Dental School	0.1727	0.3806	0.6746	1.0978	7
Minab Sports Stadium	0.2554	0.5627	0.9857	0.7659	6
Sanandaj Tourism Hotel	0.3091	0.6812	1.1982	0.5606	3
Sanandaj and Marivan Water Supply Network Reform Project	0.2628	0.5791	1.0094	0.7336	5

In Table 5, the mentioned projects are the projects in which the researcher has been active as an expert in the field of construction with a high experience. Also, the evaluation has been done according to the opinion of 10 experts in the filed of construction and civil engineering. In Table 6, the proximity factor of each option has been calculated. Each option with higher proximity factor has high priority. The positive ideal distance for each one of reconstruction options at Marivan city after the war, Beti resedintial complex at third phase of Andisheh city, Tajrish 600 hospital-bed, Zahedan dental school, Minab sport stadium, hotel of Sanandaj tourism organization and Sanandaj and Marivan water supply network reform project at Kordestan was respectively 0.7598, 0.6144, 0.4967, 1.0978, 0.7659, 0.5606 and 0.7336. Also, the negative ideal distance for each one of reconstruction options at Marivan city after the war, Beti resedintial complex at third phase of Andisheh city, Tajrish 600 hospital-bed, Zahedan dental school, Minab sport stadium, hotel of Sanandaj tourism organization and Sanandaj and Marivan water supply network reform project at Kordestan was respectively 0.5700, 0.7054, 0.8274, 0.6746, 0.9857, 1.1982 and 1.00947336. According to the fuzzy Topsis calculation using Matlab Software and after fuzzy ranking of options, Tajrish 600 hospital bed had highest priority with 0.3935 weight, Betti resedintial complex at third phase of Andisheh city with 0.3366 was in second priority and Zahedan dental school with weight of 0.1727 was in last priority.

7. Discussion and Conclusion:

One of the most important results of this paper is fuzzy TOPSIS method. Following the fuzzy ranking of options, it was found that "Tajrish 600 Hospital-Bed " with highest weight of 0.3935, " Betty Residential Complex at third phase of Andisheh city was at second with a weight of 0.3366 and Zahedan Dental School with a weight of 0.1727 place at final ranking.

Today, the simultaneous reduction of project cost and time in the competitive environment between contracting companies is critical. Therefore, contracting organizations should carefully consider different approaches to achieve an optimal time-cost balance. So far, various models have been developed, but most of them concern a situation where the project time is fixed by contract. Therefore, the goal of optimization in these cases is limited to finding a solution to minimize project costs.

By emerging the project delivery suggestion system, both the employer and the contractor seek to maximize profits and attract the opportunities to complete the project faster. The emergence of new contracts that consider enhancing the quality of project execution while reducing their time and cost requires the development of models that, in addition to time and cost, aim at evaluating and optimizing project execution methods. Reducing execution time and cost, as well as enhancing its quality, are different goals that often do not match. Therefore, these issues are called time, cost, quality balance. Experts and working objects in the field of construction and other similar fields should pay attention to psychological, environmental, contractor, consultant, and employer, because the current and operational status of these variables in construction and construction projects is not sufficiently concerned. In fact, according to experts, these factors have had a beneficial effect on reducing the time and cost of construction projects. It is recommended to implement different types of activities in different organizations and projects to control the cost and time of each project.

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