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Application of the AHP and TOPSIS in project management

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C H R O N I C L E

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A B S T R A C T

Selection of an appropriate contractor plays an important role for the success of the accomplishment of any construction project. This paper presents a multi-criteria decision making method for contractor selection. The proposed study uses six criteria, namely; Experience, Financial stability, Quality performance, Manpower resources, Equipment resources and Current workload for evaluating different contractors. Using analytical hierarchy process, the study ranks these criteria and finds the relative importance of them. Next, The technique for Order of Preference by Similarity to ideal Solution (TOPSIS) is used to rank the alternative contractors according to these criteria.

1. Introduction

Most project managers are encountered with decision environments and issues in projects which are complex in nature. There are various components involved with the contractor selection, and the interrelationships among the elements are relatively complicated. Relationships among various elements of a problem could be highly nonlinear and any change in the elements would not be necessarily associated with simple proportionality. Moreover, human value and judgement systems are essential elements of project problems. Thus, the ability to make appropriate decisions plays essential role for the success of a project (Al-Harbi, 2001).

Multiple criteria decision-making (MCDM) techniques are the main parts of decision theory and analysis. They look for more than one criterion in supporting the decision process. The primary objective of all MCDM techniques is to assist decision-makers to get some insight about the problems they encounter, to learn about organizational objectives, and through exploring these in the context of the problem to help them in detecting a preferred course of action (Al-Harbi, 2001).

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Contractor selection is one of the primary activities when a typical construction project is to be completed. Without a proper and precise method for choosing the most appropriate contractor, the performance of the project could be influenced, badly. MCDM is suggested to be a viable approach for contractor selection. The analytic hierarchy process (AHP) (Saaty, 1989) is a popular tool but it can only be employed in hierarchical decision models (Cheng & Li, 2004). When a contractor is chosen, it is important to determine the relative importance of various criteria, which are normally vague in nature (Singh & Tiong, 2005). Zavadskas et al. (2010) proposed a method for contractor selection for construction works by applying SAW-G and TOPSIS grey techniques (Hwang & Yoon, 1981). Jaskowski et al. (2010) made an assessment on contractor selection criteria weights with fuzzy AHP method. Marzouk (2008) discussed the superiority and inferiority ranking model for contractor selection. Mahmoodzadeh et al. (2007) used both AHP and TOPSIS for ranking different projects based on four criteria; namely net present value, rate of return, benefit-cost analysis and payback period.

2. The proposed study

Selection of a construction contractor is generally involved with various factors. Some of the factors are related to financial figures and profitability while others are associated with job experience, equipment, etc.

2.1. Factors influencing on selection of contractor

Fig. 1 demonstrates the factors considered for the proposed study of this paper, which could impact on a construction project. As we can see from Fig. 1, there are six factors, which are important for the selection of a contractor. The first factor, Experience, is determined by different jobs accomplished by a firm in the past such as accomplishment of similar projects in the past. The second factor, Financial stability, is determined by looking at the firm's balance sheet and statement. The third factor, Quality performance, is determined on the quality of the previous works accomplished by the firm. Manpower resources is another important factor influencing on selection of a contractor, which is determined by the number of the full time employees as well as the access to other resources. Finally, Equipment and current workload are other important factors for choosing an appropriate contractor.

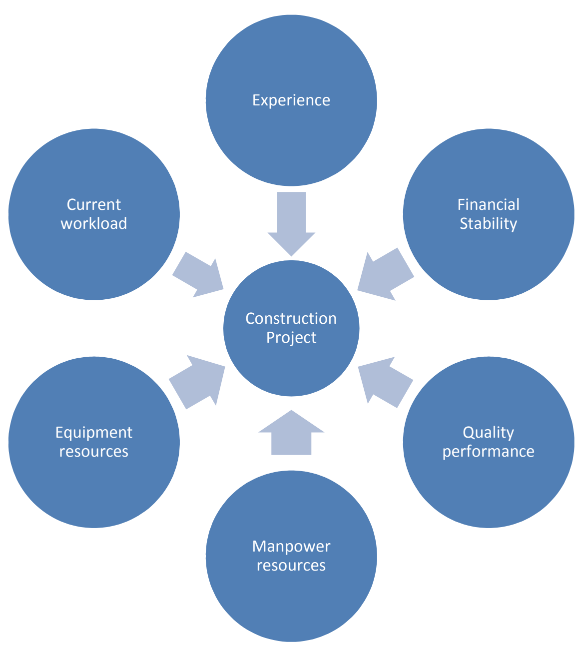

Fig. 1. The criteria influencing on choosing a construction project (Al-Harbi, 2001)

2.2. Analytical hierarchy process

Analytical hierarchy process (AHP) was first introduced by Saaty (1989) for ranking different criteria based on pairwise comparison. This method has been extensively used by many researches for ranking purposes. Al-Harbi (2001) for instance used the criteria mentioned in Fig. 1 to rank contractors.

2.2 Technique for Order of Preference by Similarity to ideal Solution (TOPSIS)

The technique for Order of Preference by Similarity to ideal Solution (TOPSIS) is considered as a multi criteria decision analysis method developed for the first time by Hwang and Yoon (1981). The method is based on the idea that the best alternative keeps the shortest geometric distance from the positive ideal solution (PIS) and maintains the longest geometric distance from the ideal negative solution (NIS). A PIS optimizes the benefit criteria / attributes. The following shows the necessary steps of TOPSIS:

Step 1: *Identifying evaluation attributes*

Identification of the aims and the assessment attributes for the study.

Step 2: *Evaluation matrix and obtaining normalized decision matrix*

Prepare an evaluation matrix, which has of *m* attributes and *n* criteria. The intersection of every attribute and criteria is given as x_{ij}. Normalize the decision matrix using the following equation:

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{M} x_{ij}^2}}, \tag{1}$$

where $i = 1, 2, \ldots m$ and $j = 1, 2, \ldots n$

Step 3: *Obtain weighted normalized matrix*

Make a decision on the relative importance (i.e. weights) of various attributes with respect to the objective in such a way that the sum weights of all attributes equals to 1.

$$\sum_{i=1}^{n} w_i = 1.$$

Obtain the weighted normalized matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized decision matrix is formed as

$$V_{ij} = w_j \times R_{ij} \tag{2}$$

where $i = 1, 2, \ldots m$, $j = 1, 2, \ldots n$ and w_j is the weight of the j^{th} attribute.

Step 4: *Determine positive ideal (V +) and negative ideal (V -) solution*

The positive ideal solution (PIS) and negative ideal solution (NIS) are chosen as follows:

$$V^+ = \left(V_1^+, V_2^+, \ldots, V_n^+\right) \text{ maximum values and } V^- = \left(V_1^-, V_2^-, \ldots, V_n^-\right) \text{ minimum values} \tag{3}$$

Step 5: *Calculate separation measures using n-dimensional Euclidean distance*

Separate every alternative from the positive ideal solution (PIS) and negative ideal solution (NIS) as follows,

$$S_j^+ = \sqrt{\sum_{i=1}^{n} \left(V_{ij} - V_i^+\right)^2} \text{ and } S_j^- = \sqrt{\sum_{i=1}^{n} \left(V_{ij} - V_i^-\right)^2}, \tag{4}$$

where $j = 1, 2, \ldots, N$.

Step 6: *Calculate closeness coefficient (P)*

Closeness coefficient (P_j) for every strategy is calculated as follows:

$$P_j = \frac{S_j^-}{S_j^+ + S_j^-} \tag{5}$$

Step 7: *Determine percentage contribution of strategy:*

The percentage contribution of every strategy is calculated as follows:

$$PC_j = \frac{P_j}{\sum P_j} \times 100 \tag{6}$$

3. Case study

The case study of the proposed method consists of selection of five contractors, A, B, C, D and E. To evaluate these five firms, six criteria are defined as stated in Fig. 1 and the criteria are first ranked using AHP method. Table 1 shows the profile of the firms which are used from an example developed by Al-Harbi (2001). Table 2 shows the results of pairwise comparison of six criteria.

Table 1
Characteristics of five contractors

	Contractor A	Contractor B	Contractor C	Contractor D	Contractor E
Experience	5 years experience	7 years experience	8 years experience	10 years experience	15 years experience
	Two similar projects	One similar project	No similar project	Two similar projects	No similar project
		Special procurement experience	1 international project		
Financial stability	$7 M assets	$10 M assets	$14 M assets	$11 M assets	$6 M assets
	High growth rate	$5.5 M liabilities	$6 M liabilities	$4 M liabilities	$1.5 M liabilities
	No liability	Part of a group of companies		Good relation with banks	
Quality performance	Good organization	Average organization	Good organization	Good organization	Bad organization
	C.M. personnel	C.M. personnel	C.M. team	Good reputation	Unethical techniques
	Good reputation	Two delayed projects	Government award	Many certificates	One project terminated
	Many certificates	Safety program	Good reputation	Cost raised in some projects	Average quality
Manpower resources	Safety program		QA/QC program		
	150 laborers	100 laborers	120 laborers	90 laborers	40 laborers
	10 special skilled laborers	200 by subcontract	Good skilled labors	130 by subcontract	260 by subcontract
Equipment resources		Availability in peaks	25 special skilled laborers		
	4 mixer machines	6 mixer machines	1 batching plant	4 mixer machines	2 mixer machines
	1 excavator	1 excavator	2 concrete transferring trucks	1 excavator	10 others
	15 others	1 bulldozer	2 mixer machines	9 others	2000 sf steel formwork
		20 others	1 excavator		6000 sf wooden formwork
		15,000 sf steel formwork	1 bulldozer		
			16 others		
			17,000 sf steel formwork		
Current works load	1 big project ending	2 projects ending (1 big + 1 medium)	1 medium project started	2 big projects ending	2 small projects started
	2 projects in mid (1 medium +1 small)		2 projects ending (1 big + 1 medium)	1 medium project in mid	3 projects ending (2 small + 1 medium)

Table 2
The results of pairwise comparison of different criteria and ranking them using AHP

	Experience	Financial Stability	Quality performance	Manpower resources	Equipment resources	Current workload
Experience	1	2	3	6	4	5
Financial Stability	0.5	1	0.3333	4	2	6
Quality performance	0.3333	3	1	4	4	2
Manpower resources	0.1667	0.25	0.25	1	0.25	2
Equipment resources	0.25	0.5	0.25	4	1	2
Current workload	0.2	0.1667	0.5	0.5	0.5	1
Rank	0.3643	0.1867	0.2357	0.0558	0.1038	0.0539

Based on the information provided in Table 1 one can assign a value from one to nine for each firm. Table 3 shows the results of the numbers. Here, higher numbers mean better position assigned for each firm.

Table 3
The data for the relative importance of different factors

Contractor	Experience	Financial Stability	Quality performance	Manpower resources	Equipment resources	Current workload
A	4	8	8	8	5	8
B	6	8	4	6	7	7
C	6	9	7	8	9	5
D	7	9	5	7	3	6
E	9	7	2	8	7	9

The implementation of TOPSIS method explained in section 2 based on the weights obtained for criteria using AHP and scores given to each firm in Table 3 yields the ranking of the firms shown in Fig. 2.

Fig. 2. The results of ranking five contractors using TOPSIS method

4. Conclusion

In this paper, we have proposed a method for contractor selection using a hybrid of analytical hierarchy process and TOPSIS. The proposed method has chosen six criteria and using AHP method ranked the relative importance of criteria. Using the weights obtained in AHP method, the proposed study has implemented TOPSIS and the results have been ranked, accordingly. The proposed study of this paper has not considered vagueness of the data based on different techniques such fuzzy or intervals numbers and we leave it for interested researchers as future study.

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