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Identification and Evaluation of Parameters Influencing the selection of Finance Project Contractors of Mashhad Water and Wastewater Company Using an AHP and Fuzzy Pramty

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ABSTRACT

For managers and decision-makers, selecting the contractor is a key decision given this fact that the contractor plays a fundamental role in any outsourced project. So, identifying and evaluating the contractors selection criteria will result in eliminating inefficient contractors from the tender process. It is needed to collect and process these criteria in order to maximize the performance of selected contractors, and to minimize the errors and mistakes in fulfilling the society needs and organization standards. Obviously, many quantitative and qualitative indicators of different importance are involved in determining the contractors' eligibility. In this paper, we are to identify the factors affecting the selection of contractors, and then, to determine the importance levels of the factors and prioritize the contractors by combining the multi-criteria methods of fuzzy AHP and fuzzy PROMETHEE. This is the first time to implement this hybrid method for solving the contractor selection problem. In this regard, first, the criteria are identified and their weights are calculated using the fuzzy AHP technique, then premier contractor is selected using the fuzzy PROMETHEE method. A real application to select finance projects' contractor in the Water and Wastewater Company of Mashhad city is considered as the base problem.

Key words : Fuzzy AHP, Fuzzy PROMETHEE, Hybrid Method, Contractors, Water and Waste Water Company.

INTRODUCTION

Problem Statement

Given the high cost of wastewater collection systems and the key role of these facilities in providing services for citizens and protecting the environment, the appropriate selection of an organ for creating and implementing the wastewater collection systems plays a fundamental role in doing further and faster projects throughout the country. The comprehensive system of municipal wastewater includes the wastewater collection channels and splits as well as the wastewater filtering section. In this system, the municipal wastewater channels convey the wastewater from the houses to treatment plant. These municipal services are usually a part of water and wastewater company's duties and are administered by this company. On the other hand, today's companies are departing toward being network-centric, or in other words, behaving in the form of small core-large network. Thus, by focusing on core capabilities and downsizing, the organizations do a limited range of activities and devolve the others to suppliers outside the organization. Accordingly, the water and wastewater companies are encouraging the private sector to involve in this field in order to downsizing and reducing the government incumbency, increasing the organization's agility, decreasing and controlling the costs, utilizing the outside expertise, and prorating

the risks. The problem studied in this paper is to select the contractor of wastewater finance projects (implementing the wastewater channels and financing by collecting the fees for wastewater splits). In doing so, after identifying the criteria, the fuzzy AHP technique paired comparisons are done and the weight of each criterion is determined. Then, the premier contractor is selected using the fuzzy PROMETHEE method.

Research Necessity

Water is a national asset. For understanding how much important the topic is, it is sufficient to note that the various types of energy can be replaced by alternatives, but there exists no alternative for healthy drinking water. Along with population growth and urban development, contamination of underground aquifers is considered as one of the greatest challenges and supplying the drinking water is one of the greatest goals of societies. According to conducted studies, the city of Mashhad in Iran with the population of about 2 million and 800 thousand will need 3.052 kilometers wastewater channel and refineries of 580^{m3} capacity a day. The lack of governmental financial resources is the greatest factor of not timely implementing the wastewater channel of Mashhad city, while collecting the wastewater of Mashhad had been and will be a great problem in accomplishing the environmental and sanitary goals of this city. Despite the fact that some activities have been planned in order to fix the pollution and environmental problems and consequently improve the level of public health, some reasons like the lack of financial resources and improper selection of contractors are of the main factors in postponing these goals. As previous studies indicate, various parameters are involved in determining the indices and their importance level, so that they or their importance may be changed depends on different projects. On the other hand, the organizations are seeking the contractors who carry out the projects with lower time and cost, and higher quality. In this research particularly, selecting the appropriate contractor in order to speed up the completion of wastewater collection networks in Mashhad city cause to preventing the penetration of wastewater and chemical materials into underground aquifers through replacing the wastewater for agricultural purposes, and consequently, speeding up the creation of urban infrastructures and reaching to the goal of sustainable urban development. Therefore, it is necessary to identify the indices and determine their importance in order to select the appropriate contractor.

Literature review

The main and foremost opinions and solutions for evaluating the competency of contractors were suggested in the late 80s and early 90s. The proposed models and methods of this time were generally based on simple decision-makings, which were made by defining some rules and criteria. (Skibnewski and Russell, 1998) suggested five methods for pre-evaluating the contractors, which include the following: dimensional measurement, two-stage pre-evaluation, large-scale strategies, pre-evaluation formula, and personal judgment. (Soenmez *et al*., 2001) proposed the methods like bespolc models, multi-criteria analysis, multi-criteria operation theory, multiple regression, and cluster analysis for selecting the appropriate contractor. (Hatush and Skitmore, 1997) categorize the information used for pre-evaluating and evaluating the tender into five categories: overall and general information that is often used to achieve the executive goals, financial information, technical information, managerial information, and security or safety information. Based on multi-criteria usability theory, (Hatush and Skitmore, 1997) proposed a method for evaluating the tender and selecting the contractor, which combines the advantages of scoring techniques and optimization models. Through conducting an extensive empirical research, (Skitmore and Ng, 1999) investigated the divergence of decision-making criteria that consulting organizations and different clientele use to pre-evaluate the contractors. Results indicated that there are significant differences in selecting the criteria for decision-making and pre-evaluating. A large part of the study was devoted to identifying the common criteria that are used for pre-evaluating and evaluating the tender. By reviewing the existing literature, (Fong and Choi, 2000) proposed 11 methods for pre-evaluation and four methods for final selection of contractors. The proposed AHP model of (Fong and Choi, 2000) divides the process of contractor selection into two stages: pre-evaluation and final selection. Since their proposed hierarchy consists of 15 criteria, at least 540 (36*15) judges should be made if the number of tenders is nine.

(Subhi and Harbi, 2001) proposed the AHP as a potential decision-making method for pre-evaluating the contractors in project management. In this research, after pre-evaluating the contractors, there exist only six criteria and standard AHP is done. Based on the applied and empirical methods of contractor selection implemented by the managers of public projects in different countries, (Palaneeswaran and Kumaranwamy, 2001) developed a model for pre-evaluating the contractors consisting three types of criteria: accountability, responsibility, and competency. (Topcu, 2004) proposed a complex decision-making model for evaluating the contractors including two separate hierarchies: the former for pre-evaluating (10 criteria), and the latter for final selecting the contractors (in which the profit and cost criteria are considered based on a decision-making model). Decision-making model prioritizes the contractors through a transform mechanism and a filtering process based on pre-determined values or calculated critical values. (Topcu, 2004) proposed a model for selecting the construction and installation contractors in turkey consisted of two stages: primarily evaluating the contractors and selecting the competent contractor amongst the qualified contractors. In this model, criteria are classified hierarchically. (Anagnostopoulos, 2004) proposed an AHP method for selecting the contractor in an open tender in which the contractors are evaluated using a 7-points scoring scale (not acceptable, very weak, weak, moderate, good, very good, and excellent) and the competent contractor is selected. Although, this scale dramatically reduces the number of paired comparisons, does not guarantee the neutrality of judges.

METHODOLOGY

Evaluating the contractors' competency and selecting the appropriate contractor is naturally a multi-criteria decision-making. Multi-criteria decision-making model is of the selector models and is implemented in order to select the most appropriate alternative amongst m available alternatives. The stages for identifying and evaluating the indices affecting the selection of contractors for finance projects of Mashhad Water and Wastewater Company and evaluating the contractors using the hybrid method of Fuzzy AHP and Fuzzy PROMETHEE is summarized in the following flowchart:

In decision-making that is associated with selecting a single solution amongst the available solutions and/or prioritizing the solutions, multi-attribute decision-making methods are more considered in recent years. Amongst them, the AHP method is used more than others in management science. AHP is one of the most popular techniques

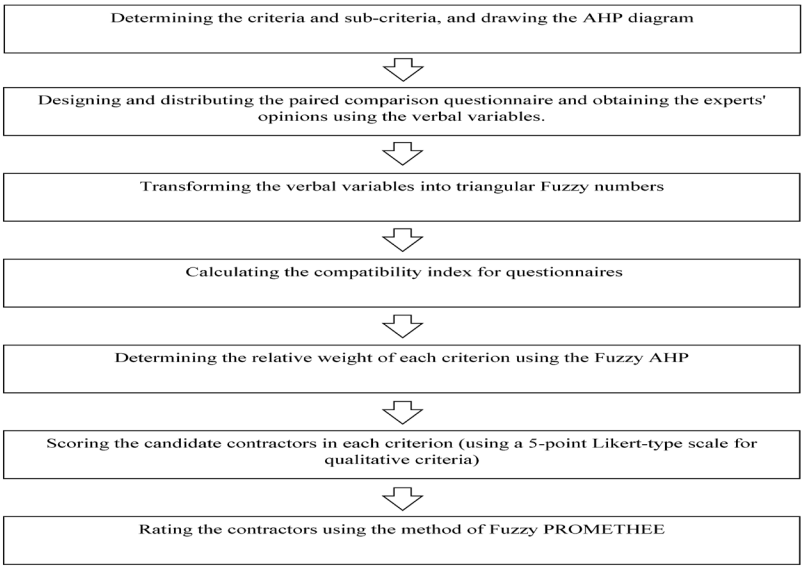

Fig. 1: Research flowchart

for multi-attribute decision-making invented by Thomas L. Saaty in 1970s. However, verbal evaluations could be used instead of numeric values when it is not possible to propose the information with a precise quantitative number. Since verbal evaluations are explained by approximate values, it is useful to implement the Fuzzy logic and especially triangular and trapezoidal membership functions in order to reduce the ambiguity of evaluations. In fact, it is recommended to use the Fuzzy AHP by implementing the triangular numbers in order to explain the ambiguous and probable opinions of decision-makers. Thus, we use Fuzzy AHP in order to determine the weights of criteria.

Stages of Fuzzy AHP (a: Modeling)

In this stage, problem and decision-making objective are presented as a hierarchy of decision elements. Decision elements include decision-making criteria and decision options. AHP divides a specific problem with several factors into a hierarchy. The top level represents for the main objective of decision-making. The second level represents for fundamental criteria (that may be divided into sub- and more-detailed criteria in the next level). The last level represents for decision options. Since the traditional AHP is not capable of reflecting the style of human thought and using the Fuzzy sets is more compatible with verbal and ambiguous explanations, it is better to engage in long-term predicting and decision-making in real world using the Fuzzy sets (implementing the Fuzzy numbers). One method for implementing the Fuzzy AHP is the Chang's developmental analysis method proposed in 1996. The numbers used in this method are triangular Fuzzy numbers and we conduct this method by making adjustments in order to combine it with Fuzzy PROMETHEE.

(b: Preferential judgment-forming the paired comparisons matrix by implementing the Fuzzy triangular numbers)

After designing the hierarchy of decision problem, decision-maker should create matrices evaluating the relative importance or preference of indices towards each other as well as evaluating each decision option than the other options. This is done through performing paired comparisons between decision elements and assigning numerical scores indicating the preference or importance of decision options. In AHP, paired comparisons table is completed as follows. In this table, a_{ij} represents for preference of criterion a_i than the criterion a_j. Obviously, preference between two identical criteria equals to one.

Instead of absolute numbers in above table, in Fuzzy AHP, the Fuzzy triangular numbers are used that are written as a triple. Definition for these numbers is slightly different in various references.

(c: Calculating Si for each row in paired comparisons table)

S_i, which is a triangular Fuzzy number is calculated from the following equation:

$$S_i = \sum_{j=1}^{n} M_{g_i}^{j} \times \left[\sum_{i=1}^{m} \sum_{j=1}^{n} M_{g_i}^{j}\right]^{-1} \quad ...(1)$$

In which i represents for number of rows, j represents for number of columns, and M^j_{gi}

C	a_1	...	a_j	...	a_n
a_1	**1**				
⋮		**1**			
a_i			a_{ij}		
⋮				**1**	
a_n					**1**

Fig. 2: Paired comparisons matrix

represents for triangular Fuzzy numbers of paired comparisons matrix. Continuing the Chang's method, largeness degree is calculated. Then, the weights of criteria in the paired comparisons matrix are calculated. For determining the final weight vector, the calculated weight vector should be normalized.

(d: Compatibility of judgments)

Calculations related to AHP are performed based on decision-maker's primary judges that are shown in the form of paired comparison matrix. Any errors or inconsistencies in the comparing and determining the importance of options distort the final obtained results. Inconsistency rate is a factor that specifies the consistency and the extent to which the obtained priorities can be trusted. Especially when the number of comparisons is high, it is difficult to trust to consistency of comparisons and consistency rate should be implemented to do so. Experience indicated that if inconsistency rate is less than 0.10, the consistency of comparisons is acceptable, otherwise the comparisons should be revised. Here, consistency index is calculated considering the middle component of Fuzzy numbers and by using the famous process proposed by Saaty.

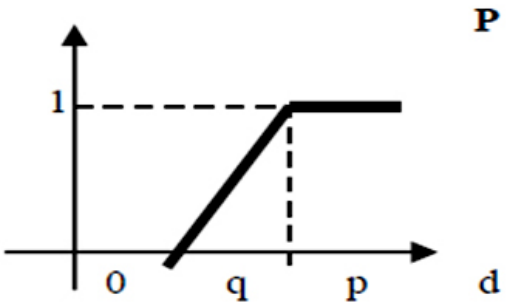

Fig. 3: Preference function used in PROMETHEE method

Table 1: Fuzzy numbers used for paired comparisons

Preferences	Number	Triangular Fuzzy number
Equal	1	(1 , 1 , 1)
Approximately equal	2	(1.2 , 1 , 3.2)
Slightly more important	3	(1 , 3.2 , 2)
More important	4	(3.2 , 2 , 5.2)
Much more important	5	(2 , 5.2 , 3)
quite more important	6	(5.2 , 3 , 7.2)

Fuzzy PROMETHEE method

PROMETHEE is a non-rating multi-criteria decision-making method used for prioritizing a large number of alternatives. PROMETHEE methods including PROMETHEE-I (partial rating) and PROMETHEE-II (full rating) have been developed by Brans in 1982, as cited in (Halouani *et al*., 2009). This method, which is used for analyzing the multi-criteria problems is simpler than the other methods conceptually, and functionally. A few years later, various versions of PROMETHEE method were developed such as PROMETHEE-III for interval rating and PROMETHEE-IV for absolute or relative rating of alternatives when we face with a set of continuous solutions. Furthermore, PROMETHEE-V for problems with constraints, PROMETHEE-VI for representing the human brain, PROMETHEE GDSS for group decision-making, and Geometrical Analysis for Interactive Aid with graphical output for making decisions that are more complex were developed. Recently, two other approaches were developed: PROMETHEE TRI for classifying problems and PROMETHEE CLUSTER for nominal classifying. Fuzzy PROMETHEE approach is used in this study in order to transform the verbal into numeric information, because the Fuzzy logic can better remove the ambiguities. PROMETHEE method is based on paired comparisons of alternatives considering each criterion. Starting point for PROMETHEE method is evaluation table in which the alternatives are evaluated based on various criteria (Macharis *et al*., 2004). Two types of

Table 2: Evaluations in PROMETHEE method (Brans *et al*., 2005)

Options	Criteria					
	$f_1(.)$	$f_1(.)$	···	$f_j(.)$	···	$f_k(.)$
a_1	$f_1(a_1)$	$f_2(a_1)$	···	$f_j(a_1)$	···	$f_k(a_1)$
a_2	$f_1(a_2)$	$f_2(a_2)$	···	$f_j(a_2)$	···	$f_k(a_2)$
·	···	···	···	···	···	···
a_i	$f_1(a_i)$	$f_2(a_i)$	···	$f_j(a_i)$	···	$f_k(a_i)$
·	···	···	···	···	···	···
a_m	$f_1(a_m)$	$f_2(a_m)$	···	$f_j(a_m)$	···	$f_k(a_m)$

additional information are required for implementing the PROMETHEE method. The first, information about the relative importance of under study criteria, and the other, information about the decision-maker's preference function of that are separately used when comparing the ratio of each alternative from the whole. To begin, suppose there is a multi-criteria problem as following:

$$Max\left\{f_{1(a)}, f_{1(a)},..., f_{n(a)} \middle| a \in A\right\} \quad ...(2)$$

In which A is a finite set of possible alternatives. $f_{j(a)}$ is the evaluation of alternative a based on criterion j. In addition, data resulted from evaluations of multi-criteria problem is presented as the following table for each criterion.

Determining the criteria weights

The weights can be determined through various methods. Here, we use Fuzzy AHP for determining the weights due to implementing the hybrid method.

Preference function

When we compare two alternatives a_t, $a_{t'} \in A$, results should be expressed based on a preference (Macharis *et al.*, 2004). In PROMETHEE method, the preference function for each criterion is often determined based on the nature of each criterion and decision-maker's perspective (Al-Badavi *et al.*, 2007). Preference function transforms the difference between two alternatives a_t ,$a_{t'}$ in terms of criterion j into a preference degree varying from zero to one. The overall preference index is calculated as following:

$$\tilde{p}(a_t) = \sum_{K=1}^{K} \tilde{w}_k \otimes P_k(\tilde{f}_k(a_t) - \tilde{f}_k(a_t)) \quad ...(3)$$

In which $\tilde{w}_k$ represents for Fuzzy weight of each criteria and a_t is a presupposed alternative. In addition, the amount of criterion for each option is considered as follows:

$$\begin{cases} \tilde{f}_k(a_t) = (m, a, b) \\ \tilde{f}_k(a_{t'}) = (n, g, d) \end{cases} \quad ...(4)$$

and we have:

$$\tilde{f}_k(a_t) - \tilde{f}_k(a_{t'}) = (m-n, a+d, b+g) \quad ...(5)$$

When the difference is obtained, the function p is applied on this new triad. In doing so:

$$\begin{cases} p_k(m-n, a+d, b+g) = \\ \left(p_k(m-n)\ p_k(m-n) - p_k(m-n-a+d)\ p_k(m-n+b+g) - p_k(m-n)\right) \end{cases} \quad ...(6)$$

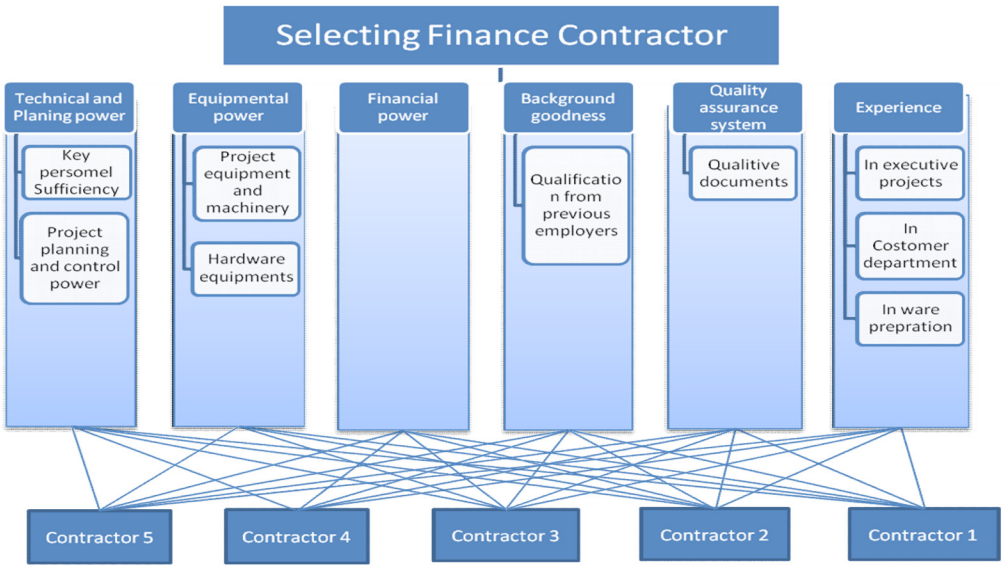

Fig. 4: Hierarchy diagram for selecting the finance contractors

Now, the positive (output) flow of preferences is calculated as following:

$$\Phi^{+}(a_t)=\frac{1}{T-1}\sum_{\substack{t'=1\\ t'\neq t}}^{T}\tilde{\rho}(a_t,a_{t'}) \quad ...(7)$$

Moreover, negative (input) flow of preferences is calculated from the following formula:

$$\Phi^{-}(a_t)=\frac{1}{T-1}\sum_{\substack{t'=1\\ t'\neq t}}^{T}\tilde{\rho}(a_{t'},a_t) \quad ...(8)$$

In which T is the number of alternatives. Here, we use the following function in order to apply the preference function:

$$P(d)=\begin{cases}0 & d\le q\\ \dfrac{d-q}{p-q} & q\langle d\le p\\ 1 & d\rangle p\end{cases} \quad ...(9)$$

Hybrid approach of Fuzzy AHP and Fuzzy PROMETHEE for selecting the appropriate contractor

After investigating the advantages and disadvantages of the two approaches of AHP and PROMETHEE, (Macharis *et al.*, 2004) suggested that the AHP approach through the appropriate structuring of problem and dividing into simpler parts and weighting the criteria can assist the PROMETHEE method having no specific technique in order to weighting the criteria: On the other hand, the PROMETHEE method can be coupled with AHP in prioritizing the alternatives because of advantages such as lower input and calculations and better software capability. On the other hand, fuzzy numbers is used in this study in order to transform the verbal into numeric information, because the Fuzzy logic can better remove the ambiguities, and finally, the hybrid method of Fuzzy AHP and PROMETHEE is proposed to solve the problem.

Table 3: Calculated weights using the Fuzzy AHP

Weights	Criteria
——-	experience
(0.06, 0.13, 0.27)	experience in executive projects
(0.03, 0.06, 0.14)	experience in supplying products
(0.04, 0.09, 0.22)	experience in customer affairs
(0.01, 0.03, 0.08)	quality assurance system
(0.02, 0.05, 0.15)	good background
——-	equipment capability
(0.08, 0.18, 0.37)	project equipment and machinery
(0.06, 0.11, 0.21)	required hardware equipment
——-	technical capability
(0.07, 0.17, 0.28)	controlling and planning capability
(0.09, 0.12, 0.22)	adequacy of key workers
(0.02, 0.06, 0.15)	financial capability

Table 4: Results for Fuzzy PROMETHEE

crisp Φ	Fuzzy Φ	$^{-}\Phi$ Fuzzy	$^{+}\Phi$ Fuzzy	options
-0.05	(-2.31, -0.07, 2.31)	(0.15, 0.18, 2.41)	(0.11, 0.11, 2.45)	Pol dezh toos Co.
-0.09	(-2.34, -0.14, 2.34)	(0.16, 0.21, 2.40)	(0.06, 0.06, 2.51)	Loomar sharq Co.
0.12	(-2.33, 0.19, 2.33)	(0.01, 0.04, 2.56)	(0.22, 0.22, 2.34)	Mashhad afra Co.
-0.04	(-2.34, -0.06, 2.34)	(0.17, 0.17, 2.40)	(0.05, 0.11, 2.51)	Amade riz Co.
-0.06	(-2.34, 0.10 , 2.41)	(0.08, 0.08, 2.48)	(0.13, 0.18, 2.43)	Sarmad sazane satrap Co.

Computational Results

In this paper, we are to answer these three fundamental questions: "what are the affecting qualitative and quantitative criteria for investigating the contractors' competency of finance projects?" and "how important are these indices for evaluating and selecting the appropriate contractor?" since the evaluating criteria of each system are different depending on its objectives, desired tasks, affecting factors, and type of costs, the following steps were made in order to identify the affecting factors of selecting the contractors. First, a number of indices were identified by reviewing the related literature, and a questionnaire was designed and distributed among the experts in order to ensure the effectiveness of identified indices in the process of contractor selection. The experts were selected from the engineers and critics with the job tenure of 12 to 18 years in different related jobs such as contracting services, project management, engineering consulting services, and the management of executive agencies. In the next step, paired comparisons questionnaire was designed in order to determine the importance of each criterion.

The relative weight of each criterion was determined through gathering the experts' opinions and using the Fuzzy group AHP and geometric mean in order to aggregate the opinions. The following table indicates the weights obtained from the Fuzzy AHP.

Finally, using the output weights of AHP method, the scores of each contractor in each criterion, and excel software, calculations relating to the rank of each contractor is obtained as the following.

CONCLUSION

Evaluating and selecting the contractor of projects is a fundamental part of construction process. Conducting applied researches in order to eliminate the various problems of construction projects such as project management, identifying the affecting factors of contractor selection, utilizing the scientific methods of selecting the fittest contractor, and finally, avoiding the waste of national resources is of special importance. This study was conducted in order to reach to several main objectives. The first objective was to identify the affecting qualitative and quantitative criteria of contractor selection, and outsourcing the activities of Water and Wastewater Company of Mashhad city. By reviewing the related literature, several criteria were identified, and then, a questionnaire was designed and distributed among the experts to ensure the effectiveness of identified factors in the process of contractor selection. Then, by gathering above data, all criteria affecting the contractor selection were identified. In the second objective, paired comparisons were made in order to determine the importance of each identified indicators for selecting the contractor of wastewater network. Accordingly, relative weight of each index was determined using the group Fuzzy AHP, and finally, the contractors were prioritized using the Fuzzy PROMETHEE approach. Identify the affecting criteria of contractor selection for finance projects of Water and Wastewater Company, weighting, and prioritizing the contractors by combining the Fuzzy AHP and Fuzzy PROMETHEE are considered in this paper for the first time in the literature. This method can be implemented in other construction projects of this company and similar companies in order to select the appropriate contractor. Future researches may utilize the other methods of multi-criteria decision-making in this field. Moreover, combining the proposed method with Monte-Carlo simulation with the aim of increasing the accuracy can be done in future.

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