The applicability of FTOPSIS and GP in Ranking (Case Study: Refinery's Contractors)

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Abstract. In today competitive world, organizations require outsourcing with regard to the activities' specialization. Outsourcing has a significant role in organizations' success and is used as a tool to create the business capabilities and advantages. One of the most important reason for outsourcing is the increase of competitive forces' pressures that imposed on organizations. All the organizations try to increase the possibility of their outsourcing projects' success in different ways. As a result, selecting contractors has become the vital issue managed by managers to maintain the organization's competitive position. The high rate of projects' failure and the importance of selecting contractors have led the organizations toward identifying the effective criteria to choose contractors. This paper has attempted to use multi-criteria methods to identify qualified contractors in which besides offered price, other factors involved in the implementation of the project are also considered. This study aimed to identify the main criteria in selecting a contractor, to determine the importance of each of them and design a proper framework for contractor selection. Major criteria for contractor selection were derived from the literature, and then the experts' views were collected using questionnaire and 6 criteria that were far more important from experts' opinion were selected. Then, the fuzzy weight of each criterion was obtained by goal programming; finally contractors were ranked through fuzzy TOPSIS method and final contractor was selected.

Keywords: *Fuzzy TOPSIS, Goal Programming (GP), Outsourcing, Ranking contractors*

1. Introduction

Outsourcing plays an important role in the success of organizations and is used as a tool to create business advantages and capabilities. This term is defined as strategic utilization from another enterprise's sources to implement the business's process. In every outsourcing activity, contractors play a critical role. It can be said that selecting contractors is the most important decision making before outsourcing. Studies show that most of the outsourcing implementation problems are because of the inappropriate way of the contractor selection. Selecting the proper contractor is a sophisticated problem that depends on many criteria. This study seeks an approach to select contractor by determining the importance rate of criteria and designing an appropriate framework.

In this research, first the ranking contractors' criteria are derived from the literature and approved by the experts, then the criteria's fuzzy pairwise comparisons and weight of criteria are determined by goal programming and in the final step, ranking contractors is done by Fuzzy TOPSIS.

This paper is organized in 4 sections. In section 1, the literature review including techniques and criteria to rank contractors is provided. Section 2 involves techniques such as fuzzy logic, trapezoidal fuzzy numbers and goal programming using pairwise comparisons to derive criteria's weight then these weights are used in TOPSIS and Fuzzy TOPSIS. In section 3 the methodology and in section 4 conclusion are proposed.

2. Literature review

Due to the role of contractors and their importance in designing, execution and implementation of diverse projects, the various methods are designed and used to select contractors by governments and in huge employer institutions in the world (Boran, Genç, Kurt, & Akay, 2009), including Multi Criteria Decision Making (MCDM) methods which help companies as the most important decision making tools. In the last decade, MCDM techniques are increasingly used to select and rank contractors (Doloi, 2009). MCDM seeks selecting one alternative among set of the alternatives on the basis of multiple criteria. For this purpose, at first, various criteria should be identified and assessed, then alternatives are valued and ranked, based on these criteria. Sum of these values exhibit the relative rank of alternatives according to mentioned problem.

Among critical MCDM techniques which are used to rank the contractors, there are some methods such as Analytic Hierarchy Process (AHP) (Juan, 2009; Watt, Kayis, & Willey, 2009), Analytic Network Process (ANP) (Fong & Choi, 2000; McCabe, Tran, & Ramani, 2005), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Boran et al., 2009), PROMETHEE (Darvish, Yasaei, & Saeedi, 2009), Multi-Attribute Analysis (MAA) (Watt et al., 2009; Zadeh, 1965), Data Envelopment Analysis (DEA) (Li, 2007; Singh & Tiong, 2006), Multi Attribute Utility Theory (MAUT) (Nieto-Morote & Ruz-Vila, 2012; Wang & Chin, 2008), Multiple Regression (MR) (Hwang & Yoon, 1981), Fuzzy Set Theory (FST) (Tsaur, Chang, & Yen, 2002;

Wang & Elhag, 2006), Multivariate discriminant Analysis (MDA) (Zadeh, 1965), etc. In the following, some articles in the field of ranking or selecting contractors are mentioned.

Table 1. Papers in selecting or ranking contractors

Author(s)	Model/Technique	Criteria/ Attributes	comment	Journal
(Zavadskas, Turskis, & Antucheviciene, 2015)	Weighted Aggregated Sum Product Assessment with Grey Values (WASPAS-G)	Bid amount, Capability and skill, Technical capacity, Managerial capability, Past performance & experience and Financial soundness	Selecting a Contractor	Studies in Informatics and Control
(Khodadadi & Kumar, 2013)	Fuzzy AHP[1]	Expertise, Financial ability, Managers & staff and Executive Records	choose the best top contractor	International Journal of Advances in Engineering & Technology
(Zala & Bhatt, 2011)	AHP	Bid price, firm's background, financial capability, technical capability, management capability, construction capability, past experience, reputation condition, health & safety policy and use of information technology & services	contractor selection	National Conference on Recent Trends in Engineering and Technology
(Zavadskas, Vilutiene, Turskis, & Tamosaitiene, 2010)	Gray TOPSIS and Gray Sao method	managers experience, construction projects performance level & amount, turnover, number of managers, market share and construction methods	select construction contractors	Journal of Business Economics and Management
(Marzouk, 2010)	elimination and choice expressing reality III (ELECTRE III)	Capital bid, Financial stability, Length of time in industry, Management organization and Experience of technical personnel	contractor selection	Innovation for Reshaping Construction Practice
(Darvish et al., 2009)	a method based on Graph theory and matrix approach	Work Experience, Technology and Equipment, Management, Experience and knowledge of the technical staff, Financial stability, Quality, Being familiar with the area or being domestic, Reputation, and Creativity & innovation	contractor ranking	International Journal of Project Management
(El-Sayegh, 2009)	decision support systems	Firm characteristics, Commercial & technical bid, Construction management services and General contracting services	selecting the appropriate construction management	Construction Management and Economics
(Anagnostopoulos & Vavatsikos, 2006)	Hierarchical model	financial performance, technical performance, safety & health policies and their past performance	assess the capabilities of civil contractors	European Online Journal of Natural and Social Sciences
(Singh & Tiong, 2005)	fuzzy set theory	tender price, past performance and performance potential	contractor selection	Journal of Construction Engineering and Management
(Cheng & Li, 2004)	AHP	Past experience, pas performance, resources, current workload, financial capability, tender price,	Contractor selection	Construction management and

[1] Analytic Hierarchy Model

		safety and past client/contractor relationship		Economics
(Topcu, 2004)	AHP	Ability to timely complete projects, Organizational expertise, Availability of experienced technical staff and Availability of resources such as machinery & equipment	construction contractor selection in the Turkish public sector	Building and environment
(Mahdi, Riley, Fereig, & Alex, 2002)	a multi-criteria decision-making method based on AHP	Experience, past performance, financial stability and project specific	support the decision process for contractors selection	Engineering Construction and Architectural Management
(Fong & Choi, 2000)	AHP	Price, Financial capability, Past performance, Past experience, Resource, Current workload, Past client/contractor relationship and Safety performance	Final contractor selection	Construction Management & Economics

As seen in table 1. most of researches are done by AHP technique. The aim of the present study is to determine qualified contractors and rank them based on fuzzy TOPSIS method.

2.1. Criteria to select contractors

In practice, different criteria are used to select contractors. But final decision has generally made on the basis of proposed price. It should be considered that the lowest price isn't always the most economic choice and may cause some problems in the field of time, quality, safety, etc. of the project implementation and expose the completion of the project to the risk and poor performance (Tsaur et al., 2002). Considering these difficulties, MCDM methods which consider offered price besides the other effective factors to implement the project are used to diagnose the competency of the contractors. In this method, it is supposed that a project will be finished very well when its contractor has many abilities and features.
Different criteria found in various studies are used to rank contractors. Table 1 shows the summary of different criteria used to rank contractors in various researches.

Table 2. Criteria of contractors ranking

	(Mahdi et al., 2002)	(Singh & Tiong, 2006)	(Hafeez, Malak, & Zhang, 2007)	(Watt et al., 2009)	(Darvish et al., 2009)	(Jaskowski, Biruk, & Bucon, 2010)	(Lam & Yu, 2011)	(Alzahrani & Emsley, 2013)	(Nieto-Morote & Ruz-Vila, 2012)
Cost and the offered price			✓	✓					
Job background and work experiment	✓	✓		✓	✓	✓	✓	✓	✓
Technology and equipment	✓				✓	✓	✓		✓
Efficient management and appropriate management system	✓			✓		✓	✓	✓	✓
Specialized knowledge					✓				
Financial stability and capability	✓	✓		✓	✓	✓	✓	✓	✓
Quality and qualitative system of implementation job	✓		✓	✓	✓			✓	

Be native and familiar to region					✓				
Fame and credibility				✓	✓				✓
Creativity and innovation					✓				✓
Personnel and technical staffs	✓			✓		✓	✓		✓
Having resources								✓	
Timely commitment and responsibility	✓		✓						
Safety and hygiene				✓		✓	✓	✓	✓
Performance on previous projects		✓		✓		✓	✓	✓	✓

As shown in table 2. the most criteria that used in ranking contractors include job background and work experiment, equipment and machines that are ready to work, efficient management, proper management system, the competency of technical personnel, knowledge, financial stability and capability, native contractor, having experience on site of the project implementation, creditability and fame, creativity and innovations in similar works, and timely commitment and responsibility.

3. Methods and techniques

The stages of this research are shown in chart 1.

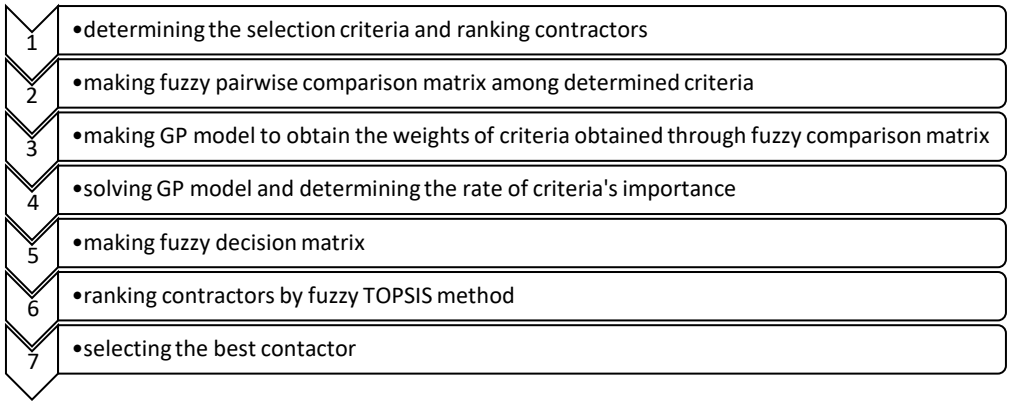

Chart 1. The research's steps

3.1 Fuzzy theory

Fuzzy sets theory was posed by Prof. Lotfizadeh in 1965. This theory is applicable at the condition of ambiguity and uncertainty. It can present many inaccurate concepts and phrases to mathematical language and provide a background to rationalize, deduce, control and decide in uncertainty conditions.

3.2 Fuzzy TOPSIS

TOPSIS[1] technique is one of the compensatory decision making methods. It has many applications in the ranking alternatives. This method was proposed in 1981 by Hwang and Yoon. Because of using qualitative attributes in this study, the fuzzy type of this model is required. In this paper, TOPSIS method in fuzzy environment with trapezoidal fuzzy numbers are used.

4. The proposed method to rank contractors

The steps of ranking refinery's contractors, on the basis of mentioned approach, are as below:

Step 1. Determining criteria's ranking and selecting contractors.

To determine the criteria to select contractors, 15 criteria are derived from the literature (see table 1), then a questionnaire that assigned the score 1 to the least important criterion and the score 9 to the most important criterion was designed and distributed among all the company's employers. The criteria that their average score was more than 4.5 were extracted and applied as the final research's criteria. Table 2 represents these criteria.

Table 2. Criteria to choose the favorite contractor by experts

Cost and proposed price	C_1
Equipment	C_2
Quality	C_3
Job background and work experiment	C_4
Financial ability	C_5
Efficient management and effectively management system	C_6

Ten company's contractors are shown by A_1 to A_{10}.

Step 2. Forming trapezoidal fuzzy pairwise matrix among criteria and dividing the matrix to four non-fuzzy matrixes.

Pairwise comparisons of six criteria determined in step 1 are done on the basis of fuzzy numbers. It starts by making primitive pairwise comparison matrix where $n_{ij} = {}^{1}/_{m_{ji}}$, $m_{ij} = {}^{1}/_{n_{ji}}$, $l_{ij} = {}^{1}/_{u_{ji}}$ and $u_{ij} = {}^{1}/_{l_{ji}}$, then the matrix is divided to four separated matrix.

Step 3. Making and solving GP model to obtain fuzzy weights related to each criterion.

Goal programming model which is used in this study is as below:

$$\text{Minimize} \quad J = e^{T}(E^{+} + E^{-} + \Gamma^{+} + \Gamma^{-} + \Delta^{+} + \Delta^{-} + \Lambda^{+} + \Lambda^{-})$$

$$\text{Subject to} \quad (B_L - I)W_U - (6-1)W_L - E^{+} + E^{-} = 0,$$
$$(B_U - I)W_L - (6-1)W_U - \Gamma^{+} + \Gamma^{-} = 0,$$
$$(B_M - I)W_N - (6-1)W_M - \Delta^{+} + \Delta^{-} = 0,$$

[1] technique for order preference by similarity to an ideal solution

$$(B_N - I)W_M - (6-1)W_N - \Lambda^+ + \Lambda^- = 0,$$

$$W_i^L + \sum_{j=1, j\neq i}^{6} W_j^U \geq 1, \quad i = 1, \dots, 6,$$

$$W_i^U + \sum_{j=1, j\neq i}^{6} W_j^L \leq 1, \quad i = 1, \dots, 6,$$

$$W_i^M + \sum_{j=1, j\neq i}^{6} W_j^N \geq 1, \quad i = 1, \dots, 6,$$

$$W_i^N + \sum_{j=1, j\neq i}^{6} W_j^M \leq 1, \quad i = 1, \dots, 6,$$

$$W_U - W_N \geq 0,$$
$$W_N - W_M \geq 0,$$
$$W_M - W_L \geq 0,$$
$$W_L, E^+, E^-, \Gamma^+, \Gamma^-, \Delta^+, \Delta^-, \Lambda^+, \Lambda^- \geq 0,$$

$$E^+ = (\varepsilon_1{}^+, \dots, \varepsilon_n{}^+)^T \geq 0, \qquad E^- = (\varepsilon_1{}^-, \dots, \varepsilon_n{}^-)^T \geq 0,$$

$$\Gamma^+ = (\gamma_1{}^+, \dots, \gamma_n{}^+)^T \geq 0, \qquad \Gamma^- = (\gamma_1{}^-, \dots, \gamma_n{}^-)^T \geq 0,$$
$$\Delta^+ = (\delta_1{}^+, \dots, \delta_n{}^+)^T \geq 0, \qquad \Delta^- = (\delta_1{}^-, \dots, \delta_n{}^-)^T \geq 0,$$
$$\Lambda^+ = (\eta_1{}^+, \dots, \eta_n{}^+)^T \geq 0, \qquad \Lambda^- = (\eta_1{}^-, \dots, \eta_n{}^-)^T \geq 0$$

The outputs of solving goal programming model are as follows:

Table 3. The outputs of solving GP model

Objective Function (Min.)	0.1029
$\mathbf{W_L}$	(0.3014, 0.1036, 0.158, 0.1038, 0.0652, 0.0417)
$\mathbf{W_M}$	(0.3358, 0.1163, 0.1917, 0.1163, 0.0738, 0.0466)
$\mathbf{W_N}$	(0.3765, 0.1359, 0.2454, 0.1359, 0.0889, 0.0711)
$\mathbf{W_U}$	(0.3765, 0.1468, 0.2703, 0.1468, 0.1025, 0.0855)
$\boldsymbol{\varepsilon_6^+}$	0.0532
$\boldsymbol{\delta_6^+}$	0.0496
$(\boldsymbol{\varepsilon_1}^-, \dots, \boldsymbol{\varepsilon_6}^-) = (\boldsymbol{\gamma_1}^-, \dots, \boldsymbol{\gamma_6}^-) = (\boldsymbol{\delta_1}^-, \dots, \boldsymbol{\delta_6}^-) = (\boldsymbol{\eta_1}^-, \dots, \boldsymbol{\eta_6}^-) = \mathbf{0}$	
$(\boldsymbol{\varepsilon_1}^+, \dots, \boldsymbol{\varepsilon_5}^+) = (\boldsymbol{\gamma_1}^+, \dots, \boldsymbol{\gamma_6}^+) = (\boldsymbol{\delta_1}^+, \dots, \boldsymbol{\delta_5}^+) = (\boldsymbol{\eta_1}^+, \dots, \boldsymbol{\eta_6}^+) = \mathbf{0}$	

Considering very small amount of objective function and the most goals getting zero amount, it can be concluded that pairwise comparison matrix is relatively consistent. The weights of six criteria are shown as trapezoidal fuzzy numbers in table 4.

Table 4. Fuzzy weights of six criteria to select contractors

	The rate of criteria's importance
$\mathbf{C_1}$	(0.3014, 0.3358, 0.3765, 0.3765)
$\mathbf{C_2}$	(0.1036, 0.1163, 0.1359, 0.1468)
$\mathbf{C_3}$	(0.1588, 0.1917, 0.2454, 0.2703)
$\mathbf{C_4}$	(0.1038, 0.1163, 0.1359, 0.1468)
$\mathbf{C_5}$	(0.0652, 0.0738, 0.0889, 0.1025)

C_6	(0.0417, 0.0466, 0.0711, 0.0855)

Step 4. Forming decision matrix related to select contractors on the basis of criteria. The score of contractors according to verbal variables is determined by experts and the following decision matrix is formed.

Step 5. Weighted normalized fuzzy decision matrix shown in table 5 was formed.

Table 5. Weighted normalized fuzzy matrix

	C_1	C_2	C_3	C_4	C_5	C_6
A_1	(0.21,0.26,0.32,0.35)	(0.06,0.08,0.10, 0.12)	(0.01,0.03,0.06, 0.08)	(0.09,0.11,0.14, 0.15)	(0.00,0.00,0.01, 0.02)	(0.04,0.04,0.07, 0.09)
A_2	(0.12,0.16,0.20,0.23)	(0.03,0.04,0.06, 0.07)	(0.09,0.12,0.17, 0.21)	(0.04,0.05,0.07, 0.09)	(0.01,0.01,0.02, 0.03)	(0.01,0.01,0.03, 0.04)
A_3	(0.16,0.21,0.26,0.29)	(0.06,0.08,0.10, 0.12)	(0.06,0.09,0.13, 0.17)	(0.04,0.05,0.07, 0.09)	(0.04,0.05,0.07, 0.09)	(0.03,0.04,0.06, 0.08)
A_4	(0.16,0.21,0.26,0.29)	(0.04,0.06,0.08, 0.10)	(0.11,0.15,0.21, 0.25)	(0.06,0.07,0.09, 0.11)	(0.03,0.04,0.05, 0.07)	(0.04,0.04,0.07, 0.09)
A_5	(0.21,0.26,0.32,0.35)	(0.04,0.06,0.08, 0.10)	(0.06,0.09,0.13, 0.17)	(0.06,0.07,0.09, 0.11)	(0.05,0.06,0.08, 0.10)	(0.04,0.04,0.07, 0.09)
A_6	(0.07,0.10,0.14,0.17)	(0.06,0.08,0.10, 0.12)	(0.04,0.06,0.09, 0.12)	(0.04,0.05,0.07, 0.09)	(0.02,0.02,0.04, 0.05)	(0.03,0.04,0.06, 0.08)
A_7	(0.25,0.28,0.38,0.38)	(0.08,0.10,0.12, 0.15)	(0.13,0.18,0.25, 0.27)	(0.06,0.07,0.09, 0.11)	(0.05,0.06,0.08, 0.10)	(0.02,0.03,0.05, 0.07)
A_8	(0.12,0.16,0.20,0.23)	(0.06,0.08,0.10, 0.12)	(0.09,0.12,0.17, 0.21)	(0.06,0.07,0.09, 0.11)	(0.02,0.02,0.04, 0.05)	(0.03,0.04,0.06, 0.08)
A_9	(0.21,0.26,0.32,0.35)	(0.03,0.04,0.06, 0.07)	(0.01,0.03,0.06, 0.08)	(0.04,0.05,0.07, 0.09)	(0.04,0.05,0.07, 0.09)	(0.00,0.00,0.01, 0.01)
A_{10}	(0.02,0.05,0.09,0.12)	(0.08,0.10,0.12, 0.15)	(0.09,0.12,0.17, 0.21)	(0.04,0.05,0.07, 0.09)	(0.01,0.01,0.02, 0.03)	(0.02,0.03,0.05, 0.07)

Steps 6 and 7. The positive and negative ideal solutions were determined and the distance of each alternative to these solutions were calculated, then in seven step the closeness index is computed and the contractors are ranked.

Table 6. The results of fuzzy TOPSIS method and the contractors' rank

	d^+	d^-	CC	Ranking
A_1	0.185535	0.234186	0.557956	5
A_2	0.195172	0.150232	0.434946	8
A_3	0.150557	0.194734	0.56397	4
A_4	0.11852	0.22431	0.65429	3
A_5	0.120766	0.244962	0.669792	2
A_6	0.253146	0.094235	0.271273	10
A_7	0.041167	0.322768	0.886883	1
A_8	0.173428	0.164939	0.487456	7
A_9	0.199466	0.223033	0.52789	6
A_{10}	0.277304	0.126438	0.313165	9

Seventh contractor with the score of upper than 0.88 is chosen as the best contractor.

5. Conclusion

Todays, outsourcing is done in all industries and in different scales. This is done with the aim of referring the job to a company which can do the work with the higher specialized level, less price and more efficient. It gains the favorable result when, as the first step, the best alternative is chosen because selecting the improper contractor not only doesn't minimize the expenditures but also can face the project with the risk of quality, time, safety, etc. The current research is done to present an accurate and comprehensive approach to select appropriate contractor. The purpose of this paper is to rank contractors, select the best contractor and recognize the critical criteria to select contractor.

The research's results are divided to two integral parts: Part 1. Deriving 15 effective criteria in selecting contractors from literature, then decreasing them to 6 criteria which are more important on the basis of experts' opinion. These criteria includes cost and the offered price, technology and equipment, quality, job background and work experiment, financial capability and efficient management and appropriate management system. The weights of these six criteria are obtained by solving goal programming model in QSB software. Part 2. Ranking and selecting the contractor which gains the highest score. In this section, fuzzy TOPSIS method is used. Another result to emerge from this study is GP model which is able to calculate the consistency rate of fuzzy pairwise comparison matrix without the need to deffuzify the matrix.

At the end future studies on the current topic, using another approach and choosing more criteria are recommended.

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