A Hybrid Swing-xTOPSIS: An Application of Ranking the Vendors at Iranian Offshore Engineering and Construction Company (IOEC)

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ARTICLE INFO

Keywords:
SUPPLIER SELECTION, MULTI ATTRIBUTE DECISION MAKING (MADM), OIL AND GAS, IOEC, SWING, TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS), FUZZY, PIPELINES

Received: 8 Jun. 2018
Revised: 29 Jul. 2018
Accepted: 16 Aug. 2018

ABSTRACT

Abstract: Since a large number of the oil and gas projects are related to the supply chain, the selection of contractors and suppliers is very important. In projects, a contractor is obliged to supply the goods from suppliers and manufacturers approved by the clients, while most companies in Iran, including the company surveyed in this research, i.e. Iranian Offshore Engineering and Construction Company (IOEC, do not have a scientific approach to this issue. The main objective of this research is providing a scientific and practical approach to ranking suppliers and contractors at IOEC and selecting the best ones. In order to achieve such an objective, an integrated model of Swing and TOPSIS methods with fuzzy approach has been designed and applied to a real case. The actual data used are obtained from the post-lay survey of the exports and infield pipelines of South Pars development phases 13, 14, and 22.

1. Introduction

In the past decade, managers have realized the important role of supply chain in value creation in companies. Rapid variations happening throughout all markets have fundamentally changed the managers' look to their environment. One of the areas the company leaders have paid more attention to is managing the purchasing and sourcing. In the past decade, purchasing management has become a competitive worldwide issue. In most industries, the cost of raw materials is the original cost of the final product, and this amount reaches approximately 19% of the final product price in production industries (Razmi et al., 2009). Therefore, the purchasing department can play a key role in the effectiveness and efficiency of a company because it can directly affect the cost reduction, flexibility, and profitability of the company. Doubtlessly, the most critical stage in the purchase process of any company is the evaluation, assessment, and selection of suppliers or vendors. Over the years, many approaches have been presented for evaluating and selecting contractors/vendors. Experts believe that, in reality, there is no unique optimal method for the evaluation and selection of contractors/vendors. Therefore, companies, based on their specific conditions, have different methods for solving this problem. The importance of the evaluation and selection of vendors/suppliers comes from the reality that materials and resources impact on activities such as production planning and control, inventory management, and production quality simultaneously. Purchase decisions are more important as companies increasingly become more dependent on their suppliers, and direct and indirect consequences of poor decision-making in this area becomes clearer (De Boer et al., 2001). An effective and efficient purchase is one of the

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activities which is important for the success in the supply chain of an engineering and construction company such as IOEC Company. The important activity of practice of buying is selecting an appropriate vendor/supplier since the selection of vendors/suppliers brings significant savings to the organization (Boran et al., 2009). IOEC, which is surveyed in this study, works in the field of offshore platform construction and oil and gas production jackets in their yards located in Khorramshahr, province of Khuzestan. Moreover, the company's major projects are related to the Iranian South Pars phases. IOEC Company should choose the ideal vendor because the vendor list provided by the employer includes many retailers having a wide range of activities; as a result, a specific model or procedure is required to evaluate and select an ideal supplier. In the current work, owing to the lack of a guide direction in this context, a scientific and applicable model and procedure for ranking vendors will be proposed.

This research aims at developing a framework for the contractor/vendor selection with the use of a multi attribute decision making (MADM) method. A case is considered to implement the framework, to choose the most suitable criteria, and to rank contractor/vendor indicators in the offshore platform construction of oil and gas industry.

2. Literature Review

In the case of decision-making evaluation models, research has been carried out to select the best contractor, and various parameters and decision-making methods have been employed. A number of previous studies in MADM and weighting methods are presented in Table 1 (Razmi et al., 2008).

In the work of Razmi et al. (2008), a basic multi-criteria model was developed which can select the best contractor for the implementation of a project by taking into account all the qualitative and quantitative factors affecting the contractor's assessment. In this model, six general criteria, some of which include their own specific sub-criteria, are presented as the effective measure to choose a contractor in a tender (Razmi et al., 2008). In this study, a hybrid multi-criteria method by the fuzzy approach is used to express variables for ranking and selecting the best contractor in the tender. Nieto-Morote and Ruz-Vila (2012) provided systematic qualification based on the fuzzy set theory. Compared to other models, the use of an algorithm for managing contradictions in relation to fuzzy preferences when using pairwise comparison judgments and the use of linguistic and accurate evaluation of the performance of contractors by quantitative and qualitative criteria are the main advantages of this model. In a study by Plebankiewicz (2012), a plan for qualifying contractors is introduced, which includes two steps: 1) in the rank and 2) in each project. Fuzzy set theory has been used to evaluate "per project" in the qualification model. Then, using a numerical example, the model performance and qualification procedures are described. Dickson's (1996) work can be considered as the pioneer of supplier assessment. In a review, he considered 23 different criteria for assessing supplier performance. Quality, delivery time, and performance history were introduced as three important criteria for this assessment. In another paper presented by Khorshid and his colleagues (2004), the evaluation and selection of suppliers in the supply chain were studied in the case of single sourcing and fuzzy approach. In the current work, linguistic terminology has been used to evaluate the performance of each supplier with respect to each criterion and to determine the weight of the criteria; the technique employed herein is ranking by fuzzy TOPSIS. Due to exploiting fuzzy TOPSIS technique, it is possible to apply quantitative and qualitative criteria simultaneously. To illustrate the validity and effectiveness of the proposed method, a numerical example, in which three decision makers (DM) pay five suppliers through the five criteria of the supplier's profitability, facilities, technological capabilities, quality, and delivery time, is also presented, and the suppliers' ratings are ultimately based on their scores.

With respect to the theoretical weakness of past researches, it should be noted that there are a variety of MADM techniques to assign weights to the criteria, but the application of several techniques to vendor selection problem has not been reported in the literature yet; Some of these technique, among others, are step-wise weight assessment ratio analysis (SWARA) (Kersuliene et al., 2010), best worst method (BWM) (Rezaei, 2015), generalized rank sum (GRS) (Wang and Zionts, 2015), correlation coefficient and standard deviation (CCSD) (Wang and Lou, 2010), and indifference threshold-based attribute ratio analysis (ITART) (Hatefi, 2019). Moreover, considering the practical vacuum of previous studies in Iran, the literature review (Safarani et al., 2017; Toosi and Samani, 2012; Afshar et al., 2011) states that there are a few organizations which have really employed the scientific models to resolve their problems of supplier selection.

3. Proposed Model

The contractor selection method proposed herein consists of three phases:

A. Determining the criteria;

B. Assigning the weights to the criteria by Swing method;

C. Contractor selection process by performing a fuzzy TOPSIS (called xTOPSIS).

Both phases B and C are performed by MADM models,

Table 1- Previous studies (Ref.: Razmi et al., 2008, completed by this work)

Reference	MADM Method	Weighting Method	Area of Research	Country
Assellaou et al. (2018)	DEMATEL (Decision Making Trial and Evaluation) (Fontela and Gabus, 1976)TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (Hwang and Yoon, 1981)	ANP (Analytic Network Process) (Saaty and Takizawa, 1986)	Refining company	Morocco
Safarani, el. al. (2017)	TOPSIS ELECTRE (Elimination and Choice Translating Reality) (Roy, 1968),VIKOR (Vlse Kriterijumsk Optimizacija Kompromisno Resenje)- (Opricović et al., 1979)	Pairwise comparison (Thurstone, 1927)	Medical equipment	Iran
Wang Chen et al. (2016)	Fuzzy TOPSIS (Chen, 2000)	Fuzzy AHP (Analytic Hierarchy Process) (Van Laarhoven and Pedrycz, 1983)	Green supplier selection	Vietnam Taiwan
Kaur et al. (2016)	Linear programming model (Schrijver, 1998) Fuzzy AHP (Chen, 2000), Fuzzy TOPSIS	Weighted IRP (Interpretive Ranking Process) (Kumar and Singh, 2015)	Industry	Switzerland India
Karsak and Dursun (2014)	QFD (Quality Function Deployment) (Akao et al., 1996), DEA (Data Envelopment Analysis) (Kretter, 1957)	Fuzzy weighted average	Private hospital	Turkey
Toosi and Samani (2012)	ANP (Saaty and Takizawa, 1986)	Pairwise comparison, SAW	Water pollution control	Iran
Eskandari et al. (2012)	SAW (Simple Additive Weighting) (Churchman and Ackoff, 1954)	Pairwise comparison (Thurstone, 1927), ROC (Rank Order Centroid) (Barron, 1992)	Landfill siting	Iran
Edwards, W. and Barron, F. H., (1994)	SMARTER (Simple Multi-attribute Rating Technique Exploiting Ranks) (Edwards and Barron, 1994)	Revised SIMOS procedure (Figueira and Roy, 2002)	Urban water conservation	Brazil
Machiwal et al. (2011)	AHP (Saaty, 1980)	Pairwise comparison (Thurstone, 1927), Eigenvector (Saaty, 1977)	Ground water potential zones	India
Ozcan et al. (2011)	TOPSIS (Hwang and Yoon ,1981), ELECTRE,Grey Theory (Deng, 1982)	SIMOS procedure (Simos, 1990)	Ware house selection	Turkey
Afshar et al. (2011)	FMCDM based on TOPSIS (Hwang and Yoon, 1981)	Fuzzy UNEP (The United Nation En Pairwise comparison (Thurstone, 1927) vironmental Program) (UNEP, 1987)	River basin	Iran
Aalianvari et al. (2012)	AHP (Saaty, 1980), Fuzzy Delphi method (Linstone, 1975)	Delphi method. pairwise comparison (Thurstone, 1927), Fuzzy weights	Potential of ground water flow	Iran
(Alipour et al. (2010)	FMCDM	Fuzzy weights	Water diversion	Iran
Chen et al. (2010)	TOPSIS (Hwang and Yoon, 1981)	Pairwise comparison (Thurstone, 1927)	Performance evaluation	China
Calizaya et al. (2010)	AHP (Saaty, 1980)	Pairwise comparison (Thurstone, 1927)	Integrated water resources management	Bolivia
Kodikara et al. (2010)	PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) (Brans, 1982)	SIMOS procedure (Simos, 1990)	Urban water supply	Australia
Vincent and Hu (2010)	Fuzzy TOPSIS	Voting method (Williams, 1780), Rating method	Evaluation of manufacturing plants	Taiwan
Garcia et al. (2010)	GP (Goal Programming) (Charnes and Cooper, 1977), TOPSIS (Hwang and Yoon, 1981)	CRITIC (Criteria Importance Through Inter-criteria Correlation) (Diakoulaki et al., 1995)	Ranking of firms	Spain
Tervonen et al. (2009)	ELECTRE Tri (Yu 1992) SMART (Edwards, 1977)	SIMOS procedure (Simos, 1990)	Sorting problems	Portugal, Finland
Shanian et al. (2008)	ELECTRE Tri (Yu, 1992)	Pairwise comparison, Eigenvector (Saaty, 1977)	Material selection	Canada, USA
Yang et al. (2008)	ANP (Saaty and Takizawa, 1986), TOPSIS (Hwang and Yoon, 1981)	Pairwise comparison (Thurstone, 1927)	Vendor selection	India
Balasubramaniam et al. (2007)	ELECTRE III (Roy, 1968) Weighted Summation	Swing (Von-Winterfeldt and Edwards, 1986)	Selection of remediation techniques for petroleum contaminated land	UK

which are widely utilized in complex decision-making, especially when there are many, and sometimes conflicting, criteria. Additionally, this research includes a real-world case study which uses interview and questionnaire techniques for collecting the required data. To present the research methodology more clearly, first of all, the literature and background of the research should be studied in order to determine the criteria, indicators, and methods of decision making. Then, for finding the useful criteria, a survey of the opinion of the IOEC experts should be carried out. After identifying the criteria and methods that can conform to the particular company circumstances in the field of offshore oil and gas industry, the questionnaires should be prepared regarding the initial investigations revealing that the combination of multi criteria decision methods is better. Also, the viewpoints of the related experts about the ranking should be asked and taken into account for ratings. Finally, the practical procedure should be submitted to the company. The above descriptions are schematically displayed in Figure 1 as the proposed process of contractors' selection.

3.1. Phase A: Determining the criteria

This phase was conducted in two stages. Stage (I): reviewing the respected state-of-the-art to create a list of any criteria reported in the literature. Stage (II): eliciting the experts' judgments to select the final criteria. With regard to stage (I), many researchers have reviewed criteria used in contractor/vendor selection and have collected them at various time intervals. The most mentioned criteria surveys are tabulated in Table 2.

Owing to stage (II), using the combination of both literature and company knowledge works in multiple ways, the company's experts and DM's can indicate which criteria should be used in the industry. For this purpose, 12 experts are selected from experienced staffers with a combination of managerial and executive positions, including project management office (PMO) manager, project managers, and operational personnel. They have about 14 to 20 years of experience in the oil and gas industry, and they are from 34 to 55 years old. The experts of IOEC are asked to select the criteria they find important in the contractor selection process with the use of a questionnaire prior to presenting the criteria from the literature in order to insure that the respondents' replies are not influenced by this information. The selected criteria are listed in Table 3. The number of times the criteria are indicated by the respondents is displayed in the right column. The criteria which are referred more than 6 time (by more than 50% of the experts) will be selected to evaluate the contractors. Interestingly, a top-ten list is obtained.

To determine the screening criteria, same as the above rule, the criteria which are selected by more than half of the experts, are selected as the screening filters of the contractors. In this case, "Price" and "Quality" were chosen as the screening criteria with being referred eight and seven times respectively.

3.2. Phase B: Criteria weight assignment

In this phase, the Swing method is used, including three stages. Stage (I): Ranking the criteria from the most important (i.e. the

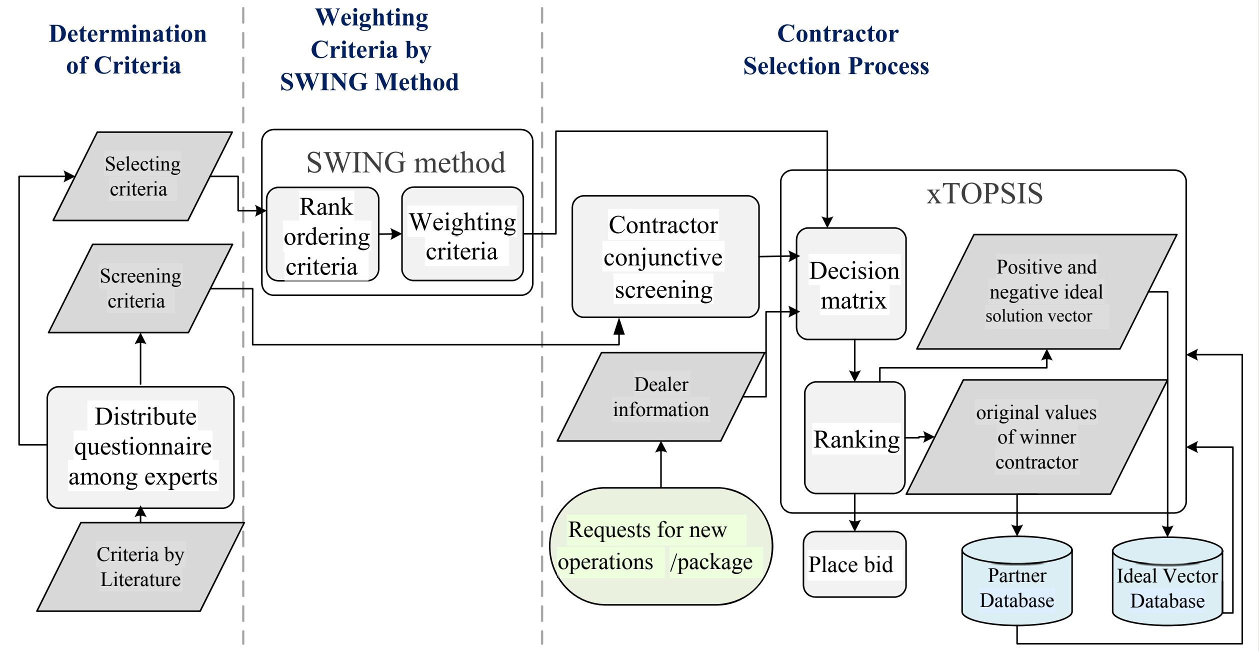

Figure 1: The proposed process of contractor selection (Ref.: this work)

highest level) to the least important one (i.e. the lowest level). Stage (II): Assigning the numerical rates to the criteria. Stage (III): Normalizing the assigned rates to get the final weights.

At stage (I), the DM is asked to consider a given option with the lowest levels of criteria. Assuming that all the criteria are at their lowest level, the DM is asked to promote one of the criteria to the highest level. This is done one after another and is repeated each time for one of the criteria. DM's preference for the sequence of the criteria is shown in the upper box of Figure 2. At stage (II), a rate of 100 is assigned to the criterion at the highest level, and

Table 2- The criteria for the supplier selection reported in the respected literature (Ref.: this work)

Criteria Name	References
Quality	Erdem and Gocen (2012), Ku et al. (2010), Doloi et al. (2011), Kibria et al. (2010), Zavadskas et al. (2008), Bendana et al. (2008), Abdel-Tawwab et al. (2008), Phillips and Dudik (2008), Singh and Tiong (2006), Gary Teng and Jaramillo (2005), Birgün Barla (2003), Palaneeswaran and Kumaraswamy (2001), Min (1994).
Price (unit cost)	Watt et al. (2009), Abdel-Tawwab et al. (2008), El-Sayegh (2009), Birgün Barla (2003), Aung et al. (2000), Masterman and Duff (1994), Singh and Murphy (1990), Skitmore and Marsden (1988).
Technical Capability	Erdem and Gocen (2012), Doloi et al. (2011), El-Sayegh (2009), Watt et al. (2009), Phillips and Dudik (2008), Abdel-Tawwab et al. (2008), Singh and Tiong (2006).
Service	Doloi et al. (2011), Ku et al. (2010), Zavadskas et al. (2008), Bendana et al. (2008), Singh and Tiong (2006), Birgün Barla (2003), Min (1994).
Production Facilities and Capacity	Watt et al. (2009), Bendana et al. (2008), Zavadskas et al. (2008), Singh and Tiong (2006), Birgün Barla (2003), Aung et al. (2000).
Delivery	Aung et al. (2000).
Financial Position	El-Sayegh (2009), Watt et al. (2009), Abdel-Tawwab et al. (2008), Bendana et al. (2008), Birgün Barla (2003), Aung et al. (2000), Min (1994).
Flexibility	Doloi et al. (2011), El-Sayegh (2009), Zavadskas et al. (2008), Abdel-Tawwab et al. (2008), Singh and Tiong (2006), Gary Teng and Jaramillo (2005), Singh and Murphy (1990), Skitmore and Marsden (1988).
Costs (ordering, transportation, etc.)	Erdem and Gocen (2012), Ku et al. (2010), Doloi et al. (2011), Abdel-Tawwab et al. (2008), Bendana et al. (2008), Phillips and Dudik (2008), Gary Teng and Jaramillo (2005), Aung et al. (2000), Min (1994).
Performance History	Doloi et al. (2011), Watt et al. (2009), El-Sayegh (2009), Phillips and Dudik (2008), Abdel-Tawwab et al. (2008), Bendana et al. (2008), Singh and Tiong (2006), Almossawi (2001), Aung et al. (2000).
Desire for Business	Palaneeswaran and Kumaraswamy (2001), Min (1994).
Trade Restrictions	Min (1994).
Labor Relation Record	Aung et al. (2000).
Geographical Location	Watt et al. (2009).
Political Situation	Bendana et al. (2008), Singh and Tiong (2006), Aung et al. (2000).
Reliability	Gary Teng and Jaramillo (2005), Birgün Barla (2003).
Reputation and Position in Industry	Watt et al. (2009), El-Sayegh (2009), Singh and Tiong (2006), Doloi et al. (2011).
Communication System	Aung et al. (2000).
Relationship	Watt et al. (2009), Bendana et al. (2008), Singh and Tiong (2006), Singh and Tiong (2006), Aung et al. (2000).
Warranty and Claim Policies	Doloi et al. (2011), Zavadskas et al. (2008), Bendana et al. (2008), Singh and Tiong (2006).
Capabilities and Standards	Erdem and Gocen (2012), Ku et al. (2010).

the DM is then asked to assign a number which matches the rest proportional to 100. The rates allocated to the criteria are shown in the middle box of Figure 2. Finally, at stage (III), the rates will be normalized to obtain the normalized weights, as the sum of the weights is equal to one. In the bottom box of Figure 2, the normalized weights are drawn.

3.3. Phase C: Contractor selection process

This phase includes two stages. Stage (I) screening the contractors/vendors with the use of conjunctive screening. Stage (II) applying an extended fuzzy-TOPSIS (called xTOPSIS) to rank the contractors.

3.3.1. Stage one: Screening vendors

The questionnaire asks the respondents (in question number 4) to state their opinion on the criterion/criteria that should be used as a minimum requirement. These are used for the conjunctive screening of the vendors (see Table 4). A screening criterion needs to be indicated by at least more than half of the experts (i.e. more than six times) in order to be incorporated in this research. The screening criteria are presented in Table 4.

According to Table 4, the fourth contractor (Dana Niroo Company) is eliminated at this stage because this vendor does not have the minimum requirement of the screening criteria.

3.3.2. Stage two: Performing xTOPSIS

In this subsection, the data gained by questionnaire is processed by xTOPSIS, and, at the end of each round, a contractor is selected and presented to the relevant units of the company. Let us, first, have some explanations of the classical TOPSIS method. TOPSIS is one of the important methods in dealing with MADM problems. It considers both the smallest distance from the positive-ideal solution and the largest distance from the negative-ideal solution. According to Kim et al. (1997), four TOPSIS advantages are as follows: (I) a sound logic that represents the rationale of human choice, (II) a scalar value that accounts for both the best and the

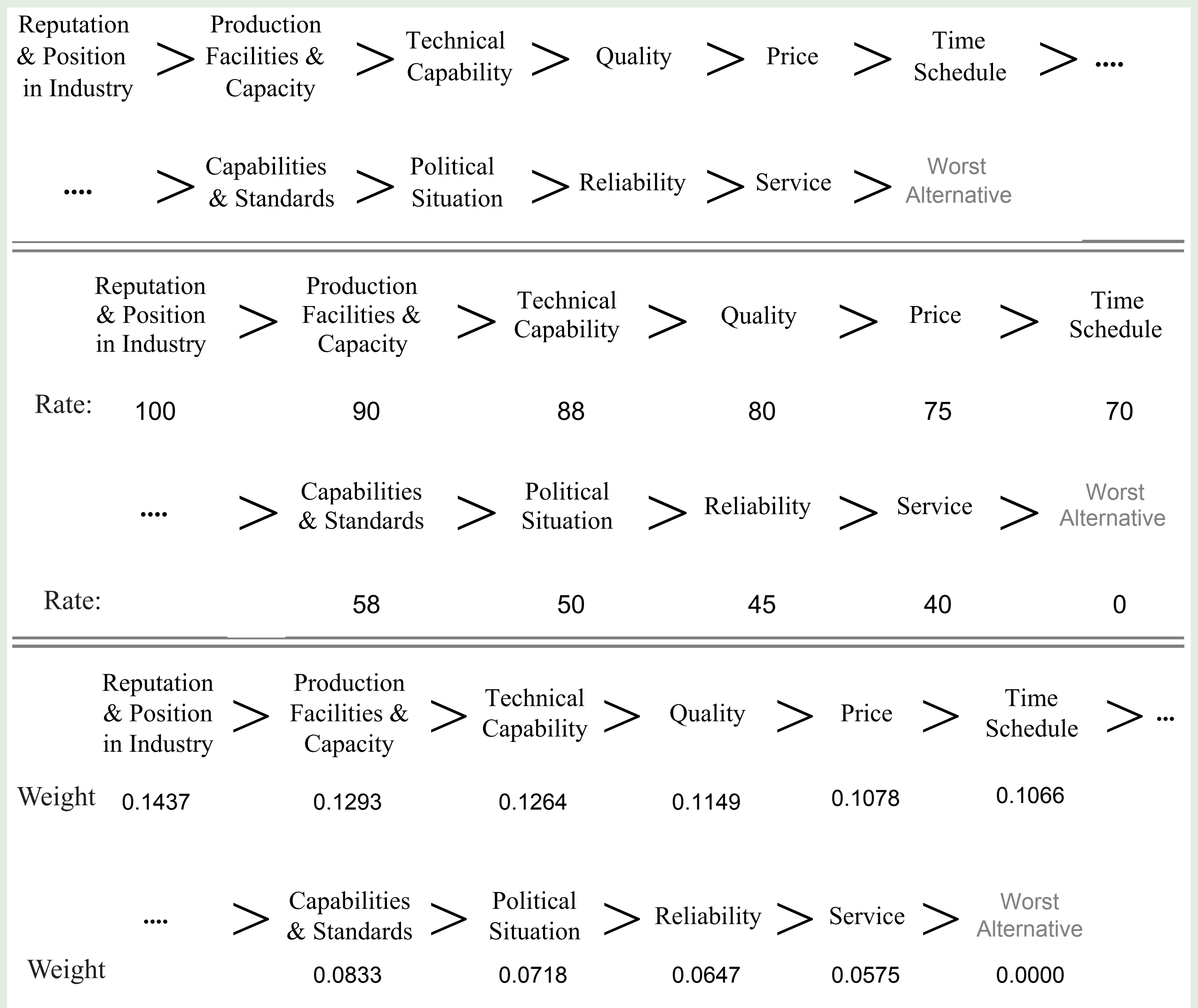

Figure 2: The proposed process of contractor selection (Ref.: this work)

Table 3- The summary result of questionnaire (Ref.: this work)

No.	Criteria	Indication
1	Reputation and Position in Industry	12
2	Quality	11
3	Production Facilities and Capacity	11
4	Technical Capability	9
5	Capabilities and Standards	9
6	Price	9
7	Time Schedule	8
8	Service	7
9	Reliability	7
10	Political Situation	6

Table 4- The screening contractors/vendors by screening criteria (Ref.: this work)

Code	Contractor Names of First Round	Screening Criteria	
		Price	Quality
C1	Akam Industry	✓	✓
C2	DANIEL Survey	✓	✓
C3	Deep Sea Offshore International	✓	✓
C4	Dana Niroo	×	✓
C5	Horizon Survey Company	✓	✓
C6	FUGRO	✓	✓

worst alternatives simultaneously, (III) a simple computation process which can be easily programmed into a spreadsheet, and (IV) the performance measures of all the alternatives of the attributes, which can be visualized on a polyhedron, at least for any two dimensions.

Human judgment and preference are often ambiguous and cannot be estimated with exact numeric values; thus, a set of crisp values is not suitable to model real-world situations (Rashid and Husnine, 2014). Probability theory, fuzzy theory, utility theory, and the models with interval or incomplete data are disciplines which aim at coping with such uncertainties. In the current paper, fuzzy theory is used to handle any imprecision in decision-making problems and the ambiguities in information (Bellman and Zadeh, 1970). Frank Schneider (2008) deduced an approach called xTOPSIS from the prerequisites of the tested and elaborated foundations and presented a numerical example to illustrate the process (Schneider, 2008). To start the first round of setting up xTOPSIS, considering the elimination of the fourth contractor in the screening step, a decision fuzzy matrix will be formed by the representative of the respective pipe-laying project. This matrix is given in Table 5.

The linguistic variables used in the decision fuzzy matrix were adjusted and equivalent to triangular fuzzy numbers. These equivalent triangular fuzzy numbers are listed in Table 6.

By using triangular fuzzy numbers equivalent to linguistic variables in Table 9, Table 5 (decision fuzzy matrix with linguistic variables) should be converted from triangular numbers to fuzzy numbers as it is presented in Table 7.

Table 5- Decision fuzzy matrix with linguistic variables (Ref.: this work)

	Criteria	Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	Weight	0.143	0.114	0.129	0.126	0.083	0.107	0.106	0.057	0.064	0.071
	aspect	(+)	(+)	(+)	(+)	(+)	(-)	(+)	(+)	(+)	(+)
	C1	Medium	Low	Extremely Low	Low	Low	Extremely High	High	High	Low	Extremely High
Contractors	C2	Medium	Medium	Extremely High	High	Medium	Medium	High	Medium	Low	Medium
	C3	High	Medium	High	Medium	Extremely High	Medium	Low	Low	Medium	Low
	C5	Low	Extremely Low	Low	High	High	Low	Medium	Medium	High	Medium
	C6	Medium	High	Medium	Medium	Extremely High	Extremely High	Low	Low	Extremely High	Extremely Low

Table 6- Triangular fuzzy numbers equivalent to linguistic variables (Ref.: this work)

Number	Linguistic	Triangular fuzzy number		
		l	m	u
1	Extremely Low	0.25	0.33	0.5
2	Low	0.33	0.5	1
3	Medium	0.5	1	2
4	High	1	2	3
5	Extremely High	2	3	4

In the second step, the decision fuzzy matrix should be normalized by employing Equations 1-4.

$$r_{ij} = \left[\frac{a_{ij}}{C_j^+} \quad \frac{b_{ij}}{C_j^+} \quad \frac{c_{ij}}{C_j^+} \right] \tag{1}$$

$$C_j^+ = \max_i C_{ij}$$

$$r_{ij} = \left[\frac{a_j^-}{c_{ij}} \quad \frac{a_j^-}{b_{ij}} \quad \frac{a_j^-}{a_{ij}} \right] \tag{2}$$

$$a_j^- = \min_i a_{ij}$$

According to Equations 3 and 4 and the weight of criteria, the normalized balanced matrix (normalized weighted decision matrix) is formed, and FPIS and FNIS are specified

Table 7- Decision fuzzy matrix with fuzzy numbers (Ref.: this work)

	Criteria	Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	Weight	0.143	0.114	0.129	0.126	0.083	0.107	0.106	0.057	0.064	0.071
	aspect	(+)	(+)	(+)	(+)	(+)	(-)	(+)	(+)	(+)	(+)
Contractors	C1	(0.5,1,2)	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)	(1,2,3)	(1,2,3)	(0.33,0.5,1)	(2,3,4)
	C2	(0.5,1,2)	(0.5,1,2)	(2,3,4)	(1,2,3)	(0.5,1,2)	(0.5,1,2)	(1,2,3)	(0.5,1,2)	(0.33,0.5,1)	(0.5,1,2)
	C3	(1,2,3)	(0.5,1,2)	(1,2,3)	(0.5,1,2)	(2,3,4)	(0.5,1,2)	(0.33,0.5,1)	(0.33,0.5,1)	(0.5,1,2)	(0.33,0.5,1)
	C5	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.33,0.5,1)	(1,2,3)	(1,2,3)	(1,2,3)	(0.5,1,2)	(0.5,1,2)	(1,2,3)	(0.5,1,2)
	C6	(0.5,1,2)	(1,2,3)	(0.5,1,2)	(0.5,1,2)	(2,3,4)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(2,3,4)	(0.25,0.33,0.5)
	FPIS(A_1+)	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(2,3,4)	(0.25,0.33,0.5)	(1,2,3)	(1,2,3)	(2,3,4)	(2,3,4)
	FNIS(A_1-)	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(1,2,3)	(0.33,0.5,1)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)

Table 8- The normalized balanced matrix (Ref.: this work)

	Criteria	Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	Weight	0.143	0.114	0.129	0.126	0.083	0.107	0.106	0.057	0.064	0.071
	aspect	(+)	(+)	(+)	(+)	(+)	(-)	(+)	(+)	(+)	(+)
Contractors	C1	(0.02,0.04,0.09)	(0.01,0.01,0.03)	(0.00,0.01,0.01)	(0.01,0.02,0.04)	(0.00,0.01,0.02)	(0.05,0.08,0.10)	(0.03,0.06,0.10)	(0.01,0.03,0.05)	(0.00,0.00,0.01)	(0.03,0.05,0.07)
	C2	(0.02,0.04,0.09)	(0.01,0.03,0.07)	(0.06,0.09,0.12)	(0.04,0.08,0.12)	(0.01,0.02,0.04)	(0.01,0.02,0.05)	(0.03,0.06,0.10)	(0.00,0.01,0.03)	(0.00,0.00,0.01)	(0.00,0.01,0.03)
	C3	(0.04,0.09,0.14)	(0.01,0.03,0.07)	(0.03,0.06,0.09)	(0.02,0.04,0.08)	(0.04,0.06,0.08)	(0.01,0.02,0.05)	(0.01,0.01,0.03)	(0.00,0.00,0.01)	(0.00,0.01,0.03)	(0.00,0.00,0.01)
	C5	(0.01,0.02,0.04)	(0.00,0.01,0.01)	(0.01,0.01,0.03)	(0.04,0.08,0.12)	(0.02,0.04,0.06)	(0.00,0.01,0.02)	(0.01,0.03,0.06)	(0.00,0.01,0.03)	(0.01,0.03,0.04)	(0.00,0.01,0.03)
	C6	(0.02,0.04,0.09)	(0.03,0.07,0.11)	(0.01,0.03,0.06)	(0.02,0.04,0.08)	(0.04,0.06,0.08)	(0.05,0.08,0.10)	(0.01,0.01,0.03)	(0.00,0.00,0.01)	(0.03,0.04,0.06)	(0.00,0.00,0.00)
	FPIS(A_1+)	(0.04,0.09,0.14)	(0.03,0.07,0.11)	(0.06,0.09,0.12)	(0.04,0.08,0.12)	(0.04,0.06,0.08)	(0.00,0.01,0.02)	(0.03,0.06,0.10)	(0.01,0.03,0.05)	(0.03,0.04,0.06)	(0.03,0.05,0.07)
	FNIS(A_1-)	(0.01,0.02,0.04)	(0.00,0.01,0.01)	(0.00,0.01,0.01)	(0.01,0.02,0.04)	(0.00,0.01,0.02)	(0.05,0.08,0.10)	(0.01,0.01,0.03)	(0.00,0.00,0.01)	(0.00,0.00,0.01)	(0.00,0.00,0.00)

by Equations 5 and 6. The normalized balanced matrix is displayed in Table 8.

$$v_{ij} = r_{ij} \times w_{ij} = \left[\frac{a_{ij}}{c_j^+} \quad \frac{b_{ij}}{c_j^+} \quad \frac{c_{ij}}{c_j^+} \right] \times (\alpha_j \quad \beta_j \quad \gamma_j)$$
$$= \left[\frac{a_{ij}}{c_j^+} \times \alpha_j \quad \frac{b_{ij}}{c_j^+} \times \beta_j \quad \frac{c_{ij}}{c_j^+} \times \gamma_j \right] \quad (3)$$

$$v_{ij} = r_{ij} \times w_{ij} = \left[\frac{a_j^-}{c_{ij}} \quad \frac{a_j^-}{b_{ij}} \quad \frac{a_j^-}{a_{ij}} \right] \times (\alpha_j \quad \beta_j \quad \gamma_j)$$
$$= \left[\frac{a_j^-}{c_{ij}} \times \alpha_j \quad \frac{a_j^-}{b_{ij}} \times \beta_j \quad \frac{a_j^-}{b_{ij}} \times \gamma_j \right] \quad (4)$$

where, wij are the assigned weights.

Table 9- The similarity and closeness to ideal solution and the ranking of alternatives (Ref.: this work)

Code	Alternative	$S^+_{1\ x,y}$	$S^-_{1\ x,y}$	$R_{1,x,y}$	Rank
C1	Akam Industry	0.40717	0.17093	0.29568	5
C2	DANIEL	0.22017	0.36295	0.62243	1
C3	Deep Sea Offshore	0.27223	0.31095	0.53319	2
C5	Horizon Survey Company	0.33520	0.24618	0.42344	4
C6	FUGRO	0.33189	0.24907	0.42872	3

$$V_j^+ = \begin{cases} \max\limits_{i=1,\dots,m} v_{ij};\ j \in B \\ \min\limits_{i=1,\dots,m} v_{ij};\ j \in C \end{cases} \quad (5)$$
$$FPIS = \{v_j^+ \mid j = 1,\dots,n\}$$

$$V_j^- = \begin{cases} \min\limits_{i=1,\dots,m} v_{ij};\ j \in B \\ \max\limits_{i=1,\dots,m} v_{ij};\ j \in C \end{cases} \quad (6)$$
$$FNIS = \{v_j^- \mid j = 1,\dots,n\}$$

Now the similarity to the ideal solution of an alternative and then the closeness to A1+ and A1- should be computed, and ranking is done based on R1x,y. The results are listed in Table 9.

Contractor number two (i.e. DANIEL Company) ranked first in the first round, and it is assumed that the contractor won the tender. Now the original values of contractor number two (the winner of tender) are stored in the partner database (PD), and the ideal vectors are saved in the ideal vector database (IVD). Table 10 and Table 11 tabulate PD and IVD. The first round of xTOPSIS procedure is finished here.

Table 10- Partner database (PD) in the first round (Ref.: this work)

Partner Database (PD)	Round Number	Selected Contractor in Round	Criteria									
			Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	1	DANIEL	(0.5,1,2)	(0.5,1,2)	(2,3,4)	(1,2,3)	(0.5,1,2)	(0.5,1,2)	(1,2,3)	(0.5,1,2)	(0.33,0.5,1)	(0.5,1,2)
	2	—	—	—	—	—	—	—	—	—	—	—

Table 11- Ideal vector database (IVD) in the first round (Ref.: this work)

Ideal Vector Database (IVD)	Round Number	FPIS & FNIS	Criteria									
			Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	1	A_1^+	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(2,3,4)	(0.25,0.33,0.5)	(1,2,3)	(1,2,3)	(2,3,4)	(2,3,4)
		A_1^-	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(1,2,3)	(0.33,0.5,1)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)
	2	A_2^+	—	—	—	—	—	—	—	—	—	—
		A_2^-	—	—	—	—	—	—	—	—	—	—

To start the next round, the research was held for about a month for "post-lay survey" bidding. Finally, the projects of South Pars development phase 13 requested bidding for similar operation for 13A and 13B export pipeline, and six contractors, which are listed and screened by the screening criteria in Table 12, submitted their proposal to IOEC Company.

Table 12- Post-lay surveying contractors in the second round (Ref.: this work)

Code	Contractor Names of First Round	Screening Criteria	
		Price	Quality
C1	Akam Industry	✓	✓
C2	RAL	✓	✓
C3	FUGRO	✓	✓
C4	Horizon Survey Company	✓	✓
C5	DANIEL Survey	✓	✓
C6	Deep Sea Offshore International	✓	✓

Table 13- The similarity and closeness to ideal solution and the ranking of alternatives in the second round (Ref.: this work)

Code	Alternative	$S^{+}_{1\ x,y}$	$S^{-}_{1\ x,y}$	$R_{1,x,y}$	Rank
C1	Akam Industry	0.34952	0.24006	0.40717	6
C2	RAL	0.13976	0.45053	0.76324	1
C3	FUGRO	0.23865	0.34983	0.59447	3
C5	Horizon Survey Company	0.33514	0.25593	0.43299	5
C6	DANIEL Survey	0.27064	0.32178	0.54316	4
	Deep Sea Offshore International	0.20462	0.38814	0.65480	2

According to Table 12, none of the contractors is eliminated in this step because they all meet the minimum requirement of the screening criteria.

The decision fuzzy matrix will be formed by the representative of the respective pipe-laying project. By using triangular fuzzy numbers equivalent to linguistic variables, "decision fuzzy matrix with fuzzy numbers" will be formed, and two ideal vectors are added to the set of alternatives forwarded from IVD (see Table 14). The built-in matrix will be normalized, and by multiplying the weight of the criteria by the vectors of the normalized decision matrix, the normalized balanced matrix (normalized weighted decision matrix) is created; FPIS and FNIS of the second round are specified by counting A1+ and A1-.

Now the similarity to the ideal solution of an alternative and then the closeness to A2+ and A2- should be computed, and ranking is done based on R2,x,y. The results are listed in Table 13.

Contractor number two, i.e. RAL Company, ranked first in the second round and it is assumed that the contractor won the tender. After closing the deal, the original values of contractor number two are again saved in the PD. We also update the ideal vectors and copy the values to our IVD (see Tables 15 and 16).

In the later round, the set of alternatives is completed

Table 14- Decision fuzzy matrix with fuzzy numbers in the second round (Ref.: this work)

	Criteria	Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	Weight	0.143	0.114	0.129	0.126	0.083	0.107	0.106	0.057	0.064	0.071
	aspect	(+)	(+)	(+)	(+)	(+)	(-)	(+)	(+)	(+)	(+)
Contractors	C1	(0.5,1,2)	(0.33,0.5,1)	(0.5,1,2)	(0.33,0.5,1)	(0.33,0.5,1)	(1,2,3)	(0.5,1,2)	(1,2,3)	(0.33,0.5,1)	(2,3,4)
	C2	(1,2,3)	(0.5,1,2)	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(1,2,3)	(0.5,1,2)	(1,2,3)	(0.5,1,2)
	C3	(0.5,1,2)	(1,2,3)	(1,2,3)	(1,2,3)	(1,2,3)	(2,3,4)	(0.33,0.5,1)	(0.33,0.5,1)	(1,2,3)	(0.25,0.33,0.5)
	C4	(0.33,0.5,1)	(0.25,0.33,0.5)	(1,2,3)	(1,2,3)	(1,2,3)	(0.5,1,2)	(0.33,0.5,1)	(0.5,1,2)	(1,2,3)	(0.5,1,2)
	C5	(0.5,1,2)	(0.5,1,2)	(0.5,1,2)	(1,2,3)	(0.5,1,2)	(1,2,3)	(1,2,3)	(0.5,1,2)	(0.33,0.5,1)	(0.5,1,2)
	C6	(1,2,3)	(0.5,1,2)	(0.5,1,2)	(0.5,1,2)	(2,3,4)	(0.5,1,2)	(1,2,3)	(1,2,3)	(1,2,3)	(0.5,1,2)
	A_1^+	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(2,3,4)	(0.25,0.33,0.5)	(1,2,3)	(1,2,3)	(2,3,4)	(2,3,4)
	A_1^-	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(1,2,3)	(0.33,0.5,1)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)
	A_2^+	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(2,3,4)	(2,3,4)	(1,2,3)	(1,2,3)	(2,3,4)	(2,3,4)
	A_2^-	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)

Table 15- Partner database (PD) of the second round (Ref.: this work)

Partner Database (PD)	Round Number	Selected Contractor in Round	Criteria									
			Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	1	DANIEL	(0.5,1,2)	(0.5,1,2)	(2,3,4)	(1,2,3)	(0.5,1,2)	(0.5,1,2)	(1,2,3)	(0.5,1,2)	(0.33,0.5,1)	(0.5,1,2)
	2	RAL	(1,2,3)	(0.5,1,2)	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(1,2,3)	(0.5,1,2)	(1,2,3)	(0.5,1,2)

Table 16- Ideal vector database (IVD) of the second round (Ref.: this work)

Ideal Vector Database (IVD)	Round Number	FPIS & FNIS	Criteria									
			Reputation & Position in Industry	Quality	Production Facilities & Capacity	Technical Capability	Capabilities & Standards	Price	Time Schedule	Service	Reliability	Political Situation
	1	A_1^+	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(2,3,4)	(0.25,0.33,0.5)	(1,2,3)	(1,2,3)	(2,3,4)	(2,3,4)
		A_1^-	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(1,2,3)	(0.33,0.5,1)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)
	2	A_2^+	(1,2,3)	(1,2,3)	(2,3,4)	(1,2,3)	(2,3,4)	(0.25,0.33,0.5)	(1,2,3)	(1,2,3)	(2,3,4)	(2,3,4)
		A_2^-	(0.33,0.5,1)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(1,2,3)	(0.33,0.5,1)	(0.33,0.5,1)	(0.33,0.5,1)	(0.25,0.33,0.5)

once more by the previous ideal vectors. Maybe some winner alternative becomes less favorable, while another one rises in similarity to the ideal solution. The reason for this development is the readjustment of scales and the relative placement of the alternatives. With a soaring number of entries in the partner database, more precise statements can be given about the quality of the decisions made by the agent. Maintaining a database with reference values of future analysis is an invaluable asset for any agents as it provides the key figures for automatic learning and self-adjustments.

4. Conclusion

The primary objective of this research was to elaborate on a suitable decision-making method for the oil and gas pipe laying projects and to develop PD and IVD databases to compare contractors in future. As the data analysis and findings indicate, it is possible for the firm to achieve cost savings by selecting the right and suitable contractor.

By the researchers' studies conducted in this paper, it was found out that in addition to quantitative factors, qualitative factors play an important role in the ranking of contractors, without which the best contractor cannot be absolutely determined; therefore, MADM models were preferably used. The paper introduced a contractor selection process which was conducted using the hybrid MADM model, including Swing method and TOPSIS model extended by the fuzzy approach. In fact, to overcome problems such as uncertainty, ambiguity, inaccurate information, etc., the fuzzy approach is implemented in the proposed model.

The proper evaluation of the contractor/vendor selection process and categories is needed in order to successfully operate at a low cost and high quality and to manage the contractor database. According to the IOEC's managers, the proposed model itself shows great potential for the selection process and makes it possible to analyze the contractors which have been at IOEC's tenders. The proposed model could be applied to understanding of the selected contractors in order to learn from the past decision-making processes in some rounds and to support additional improvement in the selection process. In the current work, the proposed model was conducted for two post-layout survey tenders, in which DANIEL Company was announced in the first bidding and RAL Company in the second bidding by the proposed model.

Taking the above explanations into account, this work has two contributions. The first contribution is combining two MADM methods, namely Swing and xTOPSIS, to solve the vendor selection problem. Secondly, this research is the first effort at IOEC to implement a scientific procedure for vendor selection instead of the traditional ones.

The authors believe that using the proposed model helps the analysts of the IOEC's vendor selection deal with its complicated activities and projects in a most effective and productive manner. The process is now conducted by only the trading commission unit at IOEC. Thus, it is recommended that the evaluation should be made in all the teams cooperating in such a way that each department should be responsible for its category. Finally, to minimize perplexities and to increase the understanding of a given rank, interpreting discussion of and guidelines on ranking are recommended.

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