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Determining Criteria for Contractor Selection for Electrical Projects in Saudi Electricity Company

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Abstract: Saudi Electricity Company serves millions of citizens in Saudi Arabia. Also, it is one of a biggest company in the region. To serve all citizens in a proper way, the company needs to establish big projects. Those projects are covered out by qualified contractors. Saudi Electricity Company faces a lot of challenges and difficulties to choose the best contractor, who are capable of delivering their projects in specific time, quality and cost. The company needs to consider many criteria and sub-criteria for selecting the best contractor. In this paper, Multi-Criteria Decision Making (MCDM) approach is used in the process of evaluating and selecting contractors. MCDM approach involves the activity of selecting between a set of several courses of action. However, among all the available choices, we might not always make 'right' decision, and there is always the possibility of a better choice yet to be considered or the correct information may have not been available initially. MCDM is concerned with the evaluation of problems with a finite number of alternatives which are especially known at the beginning of the solution process. We used fuzzy TOPSIS approach in this study, Fuzzy triangular numbers were determined and applied. Fuzzy weight of main criteria was calculated.in addition, our aim is to find the contractor that is closest to the ideal choice. After calculating Similarity Coefficient (CCi) for each contractor, we have determined the best contractor for Saudi Electricity Company. It's seems that contractor #2 is the best contractor then contractor #4 follows and so on, because they have highest Similarity Coefficient.

Keywords: Fuzzy TOPSIS; MCDM; Contractor selection; Saudi Electricity Company.

I. NTRODUCTION

In the Middle East and the Kingdom, Saudi Electricity Company is among the biggest power generation companies and also contributes to the development of power infrastructure. The company has numerous departments, and one these departments are the contracting department. The contracting department creates an environment that encourages fair procurement practices in ensuring the company accesses resources and other facilities for the company at the right time and through the use of right partners. The company spends yearly through the use of government finances and championing effective contractors is important. The Contracting Department has to select qualified contractors to accomplish the requirements of the project resulting in saving money and time resulting in the overall success of the company.

Selection methods are important for the different type of companies, which includes companies dealing in electrical, mechanical and construction fields. The selection method should include the

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expectation that the contractors have to deliver the requirements of the project within limited cost, quality and time. Numerous criteria are employed in determining the appropriate selection method.

The procedure in Saudi Electricity Company of contracting is similar to the normal processes even though after approval of the contract, the contract transforms to RFX (Request For X), which results in the application of normal contracting procedures. The contracting procedures (contracting phases) include preparation of bid package, evaluation of contractions, invitations of bids, clarifications of the bid, the opening of a bid, evaluations of bids, awarding the bid, and signing the contract. In the entire process, bid committee that is made of proponent representative, contract representative and finance member will participate in the opening meeting. The contracting department reviews the financial part while the proponent department revenues the technical bid. The final approach is the contracting department bringing together the different bids ad process into ensuring the eligible contractor signs the engagement.

Saudi Electricity Company participates and enters numerous contracts yearly and uses public resources to accomplish this requirement. The selection method and procedure of contractors depends on the nature and circumstances of the contract. In normal circumstances, the lowest bidder is usually given the contract. However, challenges exist is awarding the lowest bidder because of delays and quality of the final product/project. Through awarding the lowest bidder, Saudi Electricity Company does not consider variables such as financial statement strength, effectiveness in completing the work, contractor's equipment, previous experience and past performance. Thus, the only criterion is the cost.

The nature of the contract and circumstances associated with the contract are some of the variables used in qualifying a contractor. In the power generation sector, numerous prices and procedures are involved ranging from the technical aspect to the financing requirements. These activities require contractors with different technological and capability background. In qualification of a contractor, it is imperative to note the nature of the project and the minimal expertise and resource allocation. For example, using the lowest bid without select an appropriate contractor is inappropriate because information such as background and another accomplishment of contracting companies have not been queried. The appropriate strategy is a determination of the requirements of the project and itemizing the capacities of contractors that can accomplish the project. Therefore, the previous completions, financial strength, and resource capability are some of the components, which have to be addressed in contractor qualification. It is aimed to reduce the costs while improving the quality of the final product.

In this paper, fuzzy TOPSIS method applied to choose the best contractor having the shortest distance to the ideal solution also the farthest distance from negative ideal solution. Fuzzy TOPSIS method used for ranking problems in real situations. Fuzzy TOPSIS method have mainly three advantages which are: It takes subjective and objective criteria in the consideration, it's easy to use and it's understandable and it's computation process are straight forward.

II. LITERATURE REVIEW

Bid evaluation as discussed by [1] is a contractor selection process from numerous bidders. Using Rede Eléctrica Nacional (REN), a Portuguese Electric Transmission Company as the case study, [1] posit that the models for decision analysis presently utilized in the company for evaluating bids were created by means of decision conferencing process, which is backed by Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) software as well as multi-criteria approach.

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Basically, REN as the only Portuguese electricity transmission entity offers a number of contracts yearly; therefore [1] posit that models are always reused in related calls for tenders. For this reason, the criteria structuring needs significant care by concentrating on the created scales as well as developing models for value function rooted in qualitative pairwise evaluation decisions of desirability distinction. [1] in their study offered REN a socio-technical intervention that addresses the decision conferencing social aspects in combination with technical constituents for developing a model of multi-criteria bid evaluation by utilizing MACBETH. In view of this, MACBETH has been described as an approach for interactive multi-criteria decision analysis utilized in building a numerical value model rooted in non-numerical pairwise evaluation decisions. Contractor selection, as well as tender evaluation as mentioned by [2], has been an area of intensified debate as well as interest to companies tasked with delivering effective project outcomes.

[3] in his study established that selecting a contractor is a key factor for major project success. In this case, the Owners with the help of streamlined guidelines can outline clearly their requirements as well as select a best qualified contractor so as to carry out the project. [3] posits that this is crucially important in all industries since a qualified contractor can guarantee timely delivery, work within the required budget as well as match the expectations of the owner. A procurement method that is inefficient can lead to a number of challenges during and after the project. Besides that, the competencies factor of the contractors according to [3] is very important, and the contractors' financial abilities, successful espousal of project design and are important elements which the owners must be taken into account when selecting a contractor. Past experiences, as well as technical abilities as observed by [3], are as well important competencies elements of the contractor that must be considered in the process of evaluation.

as noted by [4] that the success, as well as failure of any project, is impacted by a number of decisions made by, or in the best interests of, the owner. Such decisions can be made at different project development stages; therefore, the prequalification of the contractor is a process of making a decision by involving different decision criteria and scores of decision-making parties. The processes of the prequalification, as well as bid evaluation as observed by [4], need sufficient and necessary criteria to be developed.

[5] define prequalification is a process whereby the contractors are screened by owners of the project or those representing them, in line with the determined set of criteria considered essential for successful completion of the project.

According to [6], a problem associated with selecting the contractor in nearly all cases is a multi-criteria problem. Citing a number of studies, [6] posit that multi-criteria techniques have been applied to solve the problems related to the evaluation of contractors.

[7] study provides a decision support system crucial for evaluating the total competitiveness of the contractor, especially with a focus on the construction industry in China. Parameters for competitiveness as argued by [7] are designed in a three-level hierarchical system, facilitating the competitiveness evaluation to be carried out at various levels. In this case, the system was designed mainly for; self-evaluation of the contractor as well as to help clients/owners to make prequalification evaluation. As mentioned by [8], the decision of selecting a contractor is made by clients/owners and the entire process has turned out to be a crucial issue in engineering projects. Scores of researchers have noticed contractors' opportunistic behavior in low-bids models, but the good quality, as well as the best economic outcomes, cannot be achieved by the lowest bidder.

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III. METHODOLOGY

This chapter discusses the research method of this study and detailed implementation of the research design. In order to evaluate each criteria for contractor selection in Saudi Electricity Company, a multi-criteria decision making approach will be used. But before that, we must list dawn all the possible criteria and sub-criteria for contractor selection in Saudi Electricity Company.

Establishing a hierarchy of decision function is the first step to reach the best contractor for any project in prequalification process. This step is done by reading previous studies then setting up meeting with managers and high expertise workers to list dawn all possible criteria and sub-criteria.

A. Previous studies:

A literature review is a very significant aspect of this thesis since a lot of literature reviews provide a lot of criteria and sub-criteria for selection a contractor. Taking all those criteria and sub-criteria in the consideration and use it in Multi-Criteria Decision Making will help a lot to provide a better recommendation and conclusion.

B. Meetings and Questioner:

In this study setting up a meeting with well expertise workers in Saudi Electricity Company is a must to list dawn all possible criteria and sub-criteria. The meeting will be with top well expertise in contracting department western region in Saudi Electricity Company and those are:

1. The manager of transmission contracts division in western sector.
2. The manager of generation and distribution contracts division in western sector.
3. The most expertise worker in generation department with more 20 years' experience.
4. The manager of general services in western sector.

The nature of the meeting will be as follow:

1. Show him all criteria and sub-criteria that learned from previous studies section.
2. Add or delete any criteria and sub criteria depend on what they say.
3. Determine weight for each criteria and sub criteria.

In this study, there are eight main criteria which are Qualification grade, Business coverage and market share, Technical Ability, Image and Reputation, Research and development, Technology innovation ability, Software development and application and last main criteria is Safety Level and performance.

C. The Hierarchy:

As it's shown in Figure 1 a set of criteria C= $\{c_1, c_2, \ldots, c_8\}$ for selecting the best contractor in Saudi Electricity Company during prequalification process. For example, C_3 stands for 'Technical Ability' of applicants and includes six sub-criteria $C_3= \{c_1,\ldots,c_6\}$ which are 'Construction plant capacity' , 'Current workload' , 'Proportion of advanced construction plant' , 'Location of head office' , 'Equipment depreciation rate' and 'Geographic knowledge of the project'. Since all of the criteria that's shown in Figure 1 are important for selection the best applicant 'contractor' in Saudi Electricity Company, all of them must be met by the assessed candidates.

Establishing a hierarchy of decision function is a must to model the different types of decision behavior. Modeling the simultaneous satisfaction done by combined the constraints to a conjunctive aggregation than the goals were combined by using a weighting contractor (W). The hierarchical structure of criteria and sub-criteria shows in figure 1.

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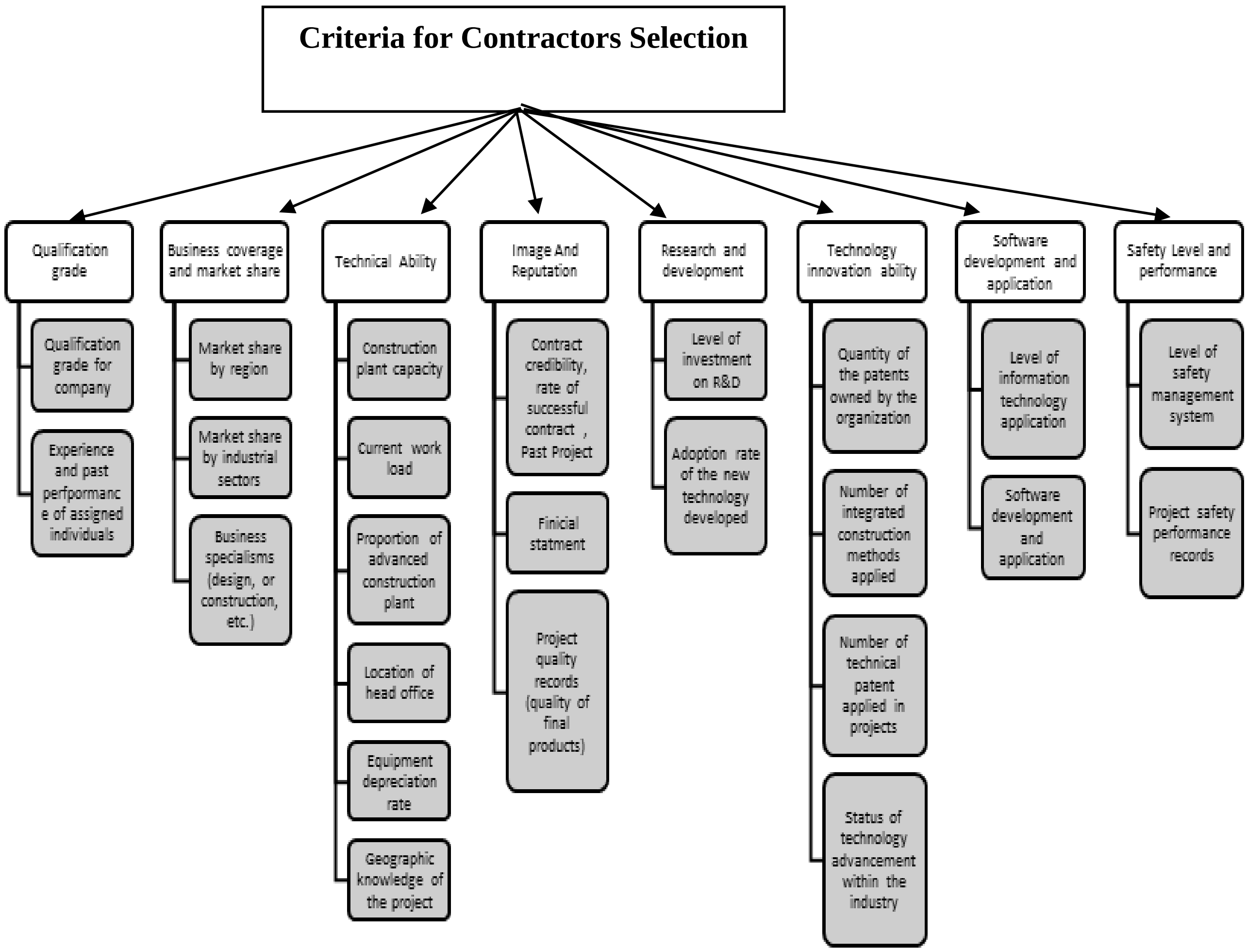

Figure 1: The criteria and sub-criteria of the prequalification contractors

The important of this study is to propose a method to determine the most eligible contractor during prequalification process in Saudi Electricity Company. In order to determine the best applicant (A_i) which is contractor, the main criteria (C_i) were divided into eight elements. Each criteria have many important sub-criteria for selecting the best contractor. The main eight criteria are for instance C_1 stands for 'Qualification grade', C_2 stands for 'Business coverage and market share', C_3 stands for 'Technical Ability', C_4 stands for 'Image And Reputation', C_5 stands for 'Research and development', C_6 stands for 'Technology innovation ability', C_7 stands for 'Software development and application' and C_8 stands for 'Safety Level and performance'. After determining all important sub-criteria, assessed and normalized by the fuzzy decision tree approach. As it's described in Figure 2, the decision tree of C_1 (qualification grade) has two sub-criteria which are 'Qualification grade for company' and 'Experience and past performance of assigned individuals', the sub-criteria set are defined by the set of weights {W_{11} and W_{12}}. Also in Figure 2, the decision tree of C_4 (Image And Reputation) have tree sub-criteria which are 'Contract credibility, rate of successful contract and Past

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Project Performance', 'Bank credibility grade' and 'Project quality records (quality of final products)', those sub-criteria defined by the set of weight {W_{41}, W_{42} and W_{43}}.

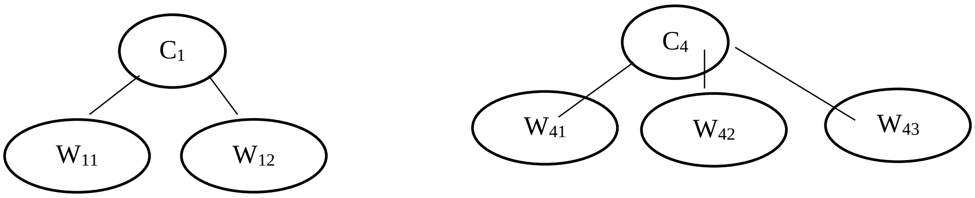

Figure 2: A fuzzy decision tree for the combination of sub-criteria by different contractors

Fuzzy linguistic terms used for the determination weight of each criteria are presented in Figure 2 The decision makers (DMs) are three top managers and top experienced of the contracting department in western region at Saudi Electricity Company. Those decision makers are selected to evaluate the performance of contractors. Table 1 shows clearly fuzzy triangular numbers and fuzzy term sets which presented the evaluation of sub-criteria weights done by fuzzy linguistic terms. To choose the best alternative for any problem, it's an important skill, especially for managers. Multiple criteria decision making is concerned with the selection of multiple important alternatives for decision maker from a finite and quantifiable alternative.

Table 1: Fuzzy linguistic terms for the weight of criteria

Fuzzy term sets	Fuzzy triangular numbers
Very low (VL)	(0, 0, 0.1)
Low (L)	(0, 0.1, 0.3)
Fair (F)	(0.1, 0.3, 0.5)
Average (A)	(0.3, 0.5, 0.7)
Average High (AH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1)
Very high (VH)	(0.9, 1, 1)

Table 2 represent the criteria of 'qualification grade' which has two sub-criteria. They are 'Qualification grade for company' and 'Experience and past performance of assigned individuals'. For example, 'Qualification grade for company' was assessed by four decision makers, and the fuzzy evaluation terms are {Very high (VH), Very high (VH), Very high (VH), High (H)}.

Table 2: Decision matrix qualification grade by fuzzy linguistic terms

Qualification grade	DM1	DM2	DM3	DM4
Qualification grade for company	VH	VH	VH	H
Experience and past performance of assigned individuals	VH	VH	H	H

Same process was applied for all criteria then listing dawn all fuzzy linguistic terms for all criteria and sub-criteria, replace each term with equivalent fuzzy triangular numbers as describe in table 3 Next step is to calculate the weights for each sub-criteria by equation 1 with N = 4, decision makers as represented in table 4

$$w_{ij} = \frac{1}{N}\{w_{ij}^{(1)} + w_{ij}^{(2)} + \cdots + w_{ij}^{(N)}\} \quad (1)$$

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Table 3: Qualification grade with equivalent fuzzy triangular numbers

Qualification grade	DM1			DM2			DM3			DM4		
Qualification grade for company	0.9	1.0	1.0	0.9	1.0	1.0	0.9	1.0	1.0	0.7	0.9	1.0
Experience and past performance of assigned individuals	0.9	1.0	1.0	0.9	1.0	1.0	0.7	0.90	1.00	0.70	0.90	1.00

$$w_{11} = \frac{(0.9,1,1) + (0.9,1,1\,) + (0.9,1,1) + (0.7,0.9,1)}{4} = (0.85, 0.975\,, 1)$$

$$w_{12} = \frac{(0.9,1,1) + (0.9,1,1\,) + (0.7,0.9,1) + (0.7,0.9,1)}{4} = (0.8, 0.97\,, 1)$$

Table 4: Weight of qualification grade aggregation

Qualification grade	Weight of sub-criteria aggregation
Qualification grade for company	(0.85 , 0.975, 1)
Experience and past performance of assigned individuals	(0.8, 0.97, 1)

The output of each averaging contractors is always will be between minimum and maximum sets. Using Equation 2 to calculate median for each criteria and given n different numbers of weights (w_{in}) with $w_{11} \leq \ldots \leq w_{in}$. By using Equation 2, the weight of 'technical ability' is C3=(0.575, 0.7625, 0.9). Table 4 represented the weights of each remaining criteria and calculated also by using equation 9.

$$med(w_{11}, \ldots, w_{1n}) = \begin{cases} w_{\frac{n+1}{2}} & if\ n\ is\ odd \\ \frac{1}{2}\left(w_{\frac{n}{2}} + w_{\frac{n}{2}+1}\right) & if\ n\ is\ even \end{cases} \quad (2)$$

Calculation of using equation 2 as follow:

$$med(Qualification\ grade\ \ ) = \frac{(0.85,0.975,1) + (0.8,0.97,1\,)}{2} = (0.825, 0.9725\,, 1)$$

Table 4: Fuzzy weight of main criteria

Main criteria	Fuzzy Attribute Weight
Qualification grade	(0.825, 0.9725, 1)
Business coverage and market share	(0.4, 0.6, 0.8)
Technical Ability	(0.575, 0.7625, 0.9)
Image And Reputation	(0.85, 0.975, 1)
Research and development	(0.3375, 0.475, 0.625)
Technology innovation ability	(0.15, 0.3, 0.5)
Software development and application	(0.3375, 0.525, 0.6875)
Safety Level and performance	(0.8, 0.95, 1)

In qualification process, each criteria for contractor selection in Saudi Electricity Company are not equally important. "Qualification grade", "Image And Reputation" and "Safety Level and performance" are most criteria have Fuzzy Attribute Weight as shown in Table 4.

D. 3.4 The TOPSIS Method for Contractor Selection in Saudi Electricity Company

The TOPSIS assumes that each of the attributes under study has the tendency of monotonically increasing or decreasing utility. It is, therefore, easy to locate the ideal and negative-ideal solutions. The Euclidean distance evaluates the relative closeness of all the present alternatives to the ideal solution. The preference in order of the alternatives is gained by comparing the relative distances [9]. There are so many techniques can deal with multi-criteria decision-making problems. One of that is TOPSIS methodology which is a goal based approach for finding the alternative that is closest to the

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ideal solution. Because it has limited subjective input is needed from the decision making, it's become an easy and simple method to use also due to the simple mathematical calculation. Also, it takes into consideration all types of criteria (subjective and objective). Table 5 presents the important of attributes and the rating of alternatives with respect to each criteria.

Table 5: Fuzzy terms and criteria rating

Fuzzy language	Fuzzy numbers
Poor (P)	(1, 2, 3)
Fair (F)	(1, 2.5, 4)
Good (G)	(2.5, 4, 5.5)
Very Good (VG)	(4, 5.5, 7)
Excellent (E)	(5.5, 7, 9)

After calculating and determining the main criteria weights in Table 6, now must rank each applicant according to their relative closeness when combining the shortest distance from positive ideal solution and the farthest distance from negative ideal solution. Table 5 present fuzzy decision matrix for contractor No.1 for each criteria. After that's calculated the average decision for each sub-criteria by using Equation 3 for n=4 decision making. Also, Table 5 presents the average decision for all sub-criteria for contractor No.1.

$$x_{ij} = \frac{1}{N}\{x_{ij}^{(1)} + x_{ij}^{(2)} + \cdots + x_{ij}^{(N)}\} \quad (3)$$

$$X_{11} = \frac{(5.5,7,9) + (2.5,4,5.5) + (5.5,7,9) + (5.5,7,9)}{4} = (4.75, 6.25, 8.125)$$

After calculating the average of decision for each sub-criteria, the fuzzy multi-criteria decision making will transform to a matrix form as shown in Equation 4

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{13} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \tilde{x}_{23} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{m3} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (4)$$

Fuzzy decision matrix of qualification contractors for each applicant shown in Table 7. Transforming the outcome for each criteria and sub-criteria to fuzzy membership value by applying fuzzy TOPSIS approach. In Table 7 the row corresponding to $A_i s, c_j$ has been calculated for each applicant by using Equation 5 and shown in Table 8

$$\tilde{R}_{ij} = [\tilde{r}_{ij}]_{mxn}$$

$$c_j^* = \max c_{ij}, \ \ if\ j \in \ B \quad (5)$$

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Table 6: Fuzzy decision matrix for Contractor No.1

X_1: Qualification grade	DM1	DM2	DM3	DM4	Average of decision
X_{11}: Qualification grade for company	E	G	E	E	(4.75, 6.25, 8.125)
X_{12}: Experience and past performance of assigned individuals	G	VG	G	E	(3.625, 5.125, 6.75)
X_2 : Business coverage and market share	DM1	DM2	DM3	DM4	Average of decision
X_{21}:Market share by region	p	p	G	F	(1.376, 2.625, 3.875)
X_{22} :Market share by industrial sectors	G	G	P	F	(1.75, 3.125, 4.5)
X_{23}:Business specialisms (design, or construction, etc.)	VG	VG	G	VG	(3.625, 5.125, 6.625)
X_2:Technical Ability	DM1	DM2	DM3	DM4	Average of decision
X_{31}:Construction plant capacity	E	E	VG	G	(4.375, 5.875, 7.625)
X_{32}:Current work load	G	G	F	E	(2.875, 4.375, 6)
X_{33}: Proportion of advanced construction plant	VG	VG	G	VG	(3.625, 5.125, 6.625)
X_{34}: Location of head office	E	E	G	G	(4, 5.5, 7.25)
X_{35}:Equipment depreciation rate	G	G	F	F	(1.75, 3.25, 4.75)
X_{36}: Geographic knowledge of the project	VG	VG	G	VG	(3.625, 5.125, 6.625)
X_4: Image And Reputation	DM1	DM2	DM3	DM4	Average of decision
X_{41}: Contract credibility, rate of successful contract , Past Project Performance	VG	E	G	VG	(4, 5.5, 7.125)
X_{42}: Bank Statement	G	G	F	G	(2.125, 3.625, 5.125)
X_{43}: Project quality records (quality of final products)	E	VG	E	VG	(4.75, 6.25, 8)
X_5: Research and development	DM1	DM2	DM3	DM4	Average of decision
X_{51}: Level of investment on R&D	VG	VG	G	VG	(3.625, 5.125, 6.625)
X_{52}: Adoption rate of the new technology developed	E	E	VG	G	(4.375, 5.875, 7.625)
X_6: Technology innovation ability	DM1	DM2	DM3	DM4	Average of decision
X_{61}: Quantity of the patents owned by the organization	VG	VG	G	VG	(3.625, 5.125, 6.625)
X_{62}: Number of integrated construction methods applied	E	E	VG	G	(4.375, 5.875, 7.625)
X_{63}: Number of technical patent applied in projects	VG	VG	G	VG	(3.625, 5.125, 6.625)
X_{64}: Status of technology advancement within the industry	E	F	G	G	(2.875, 4.375, 6)
X_7: Software development and application	DM1	DM2	DM3	DM4	Average of decision
X_{71}: Level of information technology application	E	E	G	G	(4, 5.5, 7.25)
X_{72}: Software development and application	VG	VG	G	VG	(3.625, 5.125, 6.625)
X_8: Safety Level and performance	DM1	DM2	DM3	DM4	Average of decision
X_{81}: Level of safety management system	E	E	G	G	(4, 5.5, 7.25)
X_{82}: Project safety performance records	VG	VG	G	VG	(3.625, 5.125, 6.625)

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Table 7: Fuzzy decision matrix of qualification contractors for each contractor

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(4.188,5.688, 7.438)	(1.75, 3.125, 4.5)	(3.625 ,5.125, 6.625)	(4, 5.5, 7.125)	(4, 5.5, 7.125)	(3.625, 5.125, 6.625)	(4.188, 5.688, 7.375)	(3.813, 5.313, 6.938)
A2	(3.813, 5.313, 6.938)	(4, 5.5, 7.125)	(4, 5.5, 7.125)	(4, 5.5, 7.125)	(3.813, 5.313, 6.938)	(4, 5.5, 7.188)	(3.625, 5.063, 6.688)	(3.813, 5.313, 6.938)
A3	(2.875, 4.375, 6)	(3.625, 5.125, 6.625)	(3.25, 4.75, 6.313)	(3.625, 5.125, 6.625)	(3.813, 5.313, 6.938)	(3.813, 5.313, 6.938)	(4, 5.5, 7.188)	(3.813, 5.313, 6.938)
A4	(3.25, 4.688, 6.25)	(3.625, 5.125, 6.625)	(3.625, 5.125, 6.688)	(3.625, 5.125, 6.625)	(3.25, 4.688, 6.25)	(3.813, 5.313, 6.938)	(3.813, 5.313, 6.938)	(3.813, 5.313, 6.938)
A5	(3.25, 4.75, 6.375)	(2.875, 4.375, 6)	(3.438, 4.875, 6.313)	(3.625, 5.125, 6.875)	(3.813, 5.313, 6.938)	(3.625, 5.125, 6.625)	(3.813, 5.313, 6.938)	(3.438, 4.938, 6.625)

c_1^* = max[(4.188, 5.688, 7.438), (1.75, 3.125, 4.5), (3.625, 5.125, 6.625), (4, 5.5, 7.125), (4, 5.5, 7.125), (3.625, 5.125, 6.625), (4.188, 5.688, 7.375), (3.813, 5.313, 6.938)] = 7.438

Table 8: Row Corresponding for Each Contractor

c1*=	7.438
c2*=	7.188
c3*=	7.188
c4*=	6.938
c5*=	6.938

Table 9 shows the outcome of using Equation 6, some examples of calculation:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \quad j \in B \qquad (6)$$

$$\tilde{r}_{25} = \left(\frac{0.53}{7.188}, \frac{0.739}{7.188}, \frac{0.965}{7.188}\right) = (0.53, 0.739, 0.965)$$

Table 9: The weight of each criteria after using row corresponding

Rij	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.563, 0.765, 1)	(0.235, 0.42, 0.605)	(0.487, 0.689, 0.891)	(0.538, 0.739, 0.958)	(0.538, 0.739, 0.958)	(0.487, 0.689, 0.891)	(0.563, 0.765, 0.992)	(0.513, 0.714, 0.933)
A2	(0.53, 0.739, 0.965)	(0.557, 0.765, 0.991)	(0.557, 0.765, 0.991)	(0.557, 0.765, 0.991)	(0.53, 0.739, 0.965)	(0.557, 0.765, 1)	(0.504, 0.704, 0.93)	(0.53, 0.739, 0.965)
A3	(0.4, 0.609, 0.835)	(0.504, 0.713, 0.922)	(0.452, 0.661, 0.878)	(0.504, 0.713, 0.922)	(0.53, 0.739, 0.965)	(0.53, 0.739, 0.965)	(0.557, 0.765, 1)	(0.53, 0.739, 0.965)
A4	(0.468, 0.676, 0.901)	(0.523, 0.739, 0.955)	(0.523, 0.739, 0.964)	(0.523, 0.739, 0.955)	(0.468, 0.676, 0.901)	(0.55, 0.766, 1)	(0.55, 0.766, 1)	(0.55, 0.766, 1)
A5	(0.468, 0.685, 0.919)	(0.414, 0.631, 0.865)	(0.495, 0.703, 0.91)	(0.523, 0.739, 0.991)	(0.55, 0.766, 1)	(0.523, 0.739, 0.955)	(0.55, 0.766, 1)	(0.495, 0.712, 0.955)
Weight of criteria	(0.825, 0.963, 1)	(0.4, 0.6, 0.8)	(0.575, 0.763, 0.9)	(0.85, 0.975, 1)	(0.338, 0.475, 0.625)	(0.15, 0.3, 0.5)	(0.338, 0.525, 0.688)	(0.8, 0.95, 1)

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IV. RESULTS

Table 4.1 presents the weighted fuzzy membership degree of all applicants with regards to the eights main criteria. Elements are normalized as positive triangular fuzzy numbers according to the weighted normalized fuzzy decision matrix. Those elements are ranges between one and zero.
By using Equation 7 the normalized decision matrix denoted by $\tilde{R}_{ij}$, after that using Equation 8 to calculate normalized fuzzy decision matrix also to converting the linear scale transformation fuzzy weighted membership degree.

$$c_j^* = \max c_{ij}, \quad if\ j \in B \tag{7}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \quad j \in B$$

$$a_j^- = \min a_{ij}, \qquad if\ j \in C.$$

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn}, \quad j = 1,2,\dots m\,; j = 1,2\dots,n \tag{8}$$

$$\tilde{V}_{ij} = \tilde{r}_{ij}\,(.)\tilde{w}_j$$

Examples are shown below:

$$\tilde{V}_{25} = (0.53, 0.739, 0.965)\,(.)\,(0.338, 0.475, 0.625) = (0.179, 0.351, 0.603)$$

$$\tilde{V}_{34} = (0.504, 0.713, 0.922)(.)\,(0.85, 0.975, 1) = (0.429, 0.695, 0.922)$$

Determining the distance of each contractor from the ideal value to fuzzified the ranges. After that's we need to calculate the distance of each alternative contractor by define both fuzzy positive ideal solution and fuzzy negative ideal solution as shown below:

$A^* = (\tilde{V}_1^*, \tilde{V}_2^*, \dots, \tilde{V}_n^*), \quad A^- = (\tilde{V}_1^-, \tilde{V}_2^-, \dots, \tilde{V}_n^-)$

Where $\tilde{V}_j^*$= (1,1,1) and $\tilde{V}_j^-$ = (0,0,0) , j = 1,2,…,n. Hence,

$$A^* = [(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1),(1,1,1)]$$

$$A^- = [(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0),(0,0,0))]$$

Table 10: The weighted fuzzy membership degrees of contractor with regard to the main criteria

Rij	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.464, 0.736, 1)	(0.094, 0.252, 0.484)	(0.28, 0.525, 0.802)	(0.457, 0.721, 0.958)	(0.182, 0.351, 0.599)	(0.073, 0.207, 0.445)	(0.19, 0.401, 0.682)	(0.41, 0.679, 0.933)
A2	(0.438, 0.711, 0.965)	(0.223, 0.459, 0.793)	(0.32, 0.583, 0.892)	(0.473, 0.746, 0.991)	(0.179, 0.351, 0.603)	(0.083, 0.23, 0.5)	(0.17, 0.37, 0.64)	(0.424, 0.702, 0.965)
A3	(0.33, 0.586, 0.835)	(0.202, 0.428, 0.737)	(0.26, 0.504, 0.79)	(0.429, 0.695, 0.922)	(0.179, 0.351, 0.603)	(0.08, 0.222, 0.483)	(0.188, 0.402, 0.688)	(0.424, 0.702, 0.965)
A4	(0.386, 0.65, 0.901)	(0.209, 0.443, 0.764)	(0.3, 0.563, 0.868)	(0.444, 0.72, 0.955)	(0.158, 0.321, 0.563)	(0.082, 0.23, 0.5)	(0.185, 0.402, 0.688)	(0.44, 0.727, 1)
A5	(0.386, 0.659, 0.919)	(0.166, 0.378, 0.692)	(0.285, 0.536, 0.819)	(0.444, 0.72, 0.991)	(0.185, 0.364, 0.625)	(0.078, 0.222, 0.477)	(0.185, 0.402, 0.688)	(0.396, 0.676, 0.955)

By using Equations 9 and 10 the distance of each alternative contractor from A^* and A^- was calculated.

$$d_i^* = \sum_{j=1}^{n} d(\tilde{V}_{ij}, \tilde{V}_j^*), \quad i = 1,2,\dots,m, \tag{9}$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{V}_{ij}, \tilde{V}_j^-), \quad i = 1,2,\dots,m, \tag{10}$$

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$\tilde{V}_{ij}$ *and* $\tilde{V}_j^*$ are two triangular fuzzy numbers of the Euclidean distance, and the distance measurement between two fuzzy numbers is defined as $d(d_i^*, d_i^-)$. The calculation shown below:

$$d_1^* = \sqrt{\frac{(1-0.464)^2+(1-0.736)^2+(1-1)^2}{3}} + \cdots + \sqrt{\frac{(1-0.41)^2+(1-0.679)^2+(1-0.933)^2}{3}} = 4.368742667$$

$$d_1^- = \sqrt{\frac{(0-0.464)^2+(0-0.736)^2+(0-1)^2}{3}} + \cdots + \sqrt{\frac{(0-0.41)^2+(0-0.679)^2+(0-0.933)^2}{3}} = 4.279983602$$

After calculate d_1^* and d_1^- next step is to calculate the closeness coefficient to rank all contractors by using Equation 11 as shown in Table 11

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad i = 1, 2\ldots, m. \tag{11}$$

Some examples for how using equation 11 are written below:

$$CC_1 = \frac{4.279983602}{4.368742667 + 4.279983602} = 0.494868663$$

$$CC_3 = \frac{4.32715185}{4.344471442 + 4.32715185} = 0.499001364$$

Table 11: The Fuzzy weighted decision matrix for each contractor

Rij	FPIS (di*)	FNIS(di-)	Similarity coefficient (CCi)	Ranking of Contractors
A1	4.368742667	4.279983602	0.494868663	5
A2	4.134062408	4.597062936	0.526514367	1
A3	4.344471442	4.32715185	0.499001364	4
A4	4.222388715	4.498013307	0.515803434	2
A5	4.297687298	4.41968325	0.506997291	3

After calculating Similarity Coefficient (CCi) for each contractor as shown in Table 11, we can use the results of it to compare it to each other and rank it. As shown in Table 11 it's clearly contractor A2 is the best contractor then come contractor A4 respectively.

V. CONCLUSION

One of the biggest problems in Saudi Electricity Company was selecting the best contractor for a project. Using Multi-Criteria Decision Making will help the company a lot in the process of selecting the best contractor. Finding the contractor that is closest to the ideal solution it's the use of TOPSIS methodology. By using Equation 2 and Table 1 average decision for each sub-criteria was calculated and shown in Table 4.

After applying fuzzy TOPSIS approach to transform the outcome for each criteria and sub-criteria to fuzzy membership value as shown in Table 7. Next, applying Equation 5 to calculate row corresponding for each contractor which shown in Table 8.

The last step is calculating the weighted fuzzy membership degrees of a contractor with regard to the main criteria and use equation 9, 10 and 11 to find similarity coefficient and ranking of contracting which presents in Table 11.

VI. RECOMMENDATION

- Develop more criteria and sub-criteria: This study has been identified eight main criteria's and each of them has several of sub-criteria mainly for Saudi Electricity Company. Develop more criteria and sub- criteria to fit more companies and industries are recommended.

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- Develop software program and link it between companies and contractors: This study has been developing an Excel sheet to do all calculation shown in chapter 4, it's recommended to develop a software program and link it with contractors and companies to be easy for contractors to see their weakness and strength so they can develop their weakness.
- Develop Decision Support System: By developing Decision Support System (DSS) will help decision makers to make decisions more easily and sufficient. Also, DSS will help decision makers to support their decisions

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Ethical statement: The authors declare that they have followed ethical responsibilities.

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