Application of Integrated MCDM Models for Construction Contractors' Selection at Al-Quds University

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***Abstract*:** The first step to the success of any construction project at Al-Quds University is to choose the right contractor to construct a project. Therefore, the university's engineering office must choose the contractors in a correct and practical method. Note that the process of selecting a contractor is a complex and not as simple as it may seem. As the selection of the contractor is subject to several criteria in various respects. Some of these criteria are important, but when compared with others, they become less important in the decision-making process. The importance of these criteria may differ from one project to another. Accordingly, this paper analyzes the current method for selecting contractors at Al-Quds University, studies the criteria and mechanisms for selecting contractors approved by the official authorities, and applies multi-criteria decision-making models that based on AHP-TOPSIS and AHP-MOORA to find the appropriate contractor for Al-Quds University construction buildings. The results from these two models are compared and investigated.

Keywords: Contractor's Selection, Multi-Criteria Decision Making, MCDM, AHP, TOPSIS, MOORA.

I. INTRODUCTION

Multi Criteria Decision Making (MCDM) is a technique employed when making complex decisions. There are many applications for MCDM and each one differs from one another. However, each method in MCDM helps decision-makers to rank or choose between the alternatives being evaluated. With the continuing proliferation of decision methods and their variants, it is important to understand their comparative value. Each of the methods uses numeric techniques to help decision-makers choose among a discrete set of alternative decisions. This is achieved based on the impact of the alternatives on certain criteria and thereby on the overall utility of the decision-maker(s). The difficulty that always occurs when trying to compare decision methods and choose the best one is that a paradox is reached. One of the applications that use MCDM technique is contractor's selection in construction industry. Hence, scholars began to develop techniques to make the decision according to multiple criteria (MCDM), such as: analytic hierarchy process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Multi-Objective Optimization based On Ratio Analysis (MOORA).

One of widely MCDM techniques used is AHP. It is applied in group decision making. Decision-makers use the AHP method to decide in diverse situations. It is common in many fields such as education, business, and management. Instead of recommending a "correct decision," the tool helps decision-makers to make choices that suit their goal and resolves their problems [1]. TOPSIS is an important decision-making technique for finding the alternative that is closest to the ideal solution. In this method, options are graded based on ideal solution similarity. If an option is more like an ideal

solution, it has a higher grade. MOORA is another reliable method for deciding between multiple objectives.

Al-Quds University, as an educational sector, began to add many academic specializations within its scientific programs. This leads to the need for new buildings, and as usual, before starting any project, the project must be presented to the contractors, and usually a large group of contractors trying to earn it. This paper explains how two MCDM integrated models (AHP-TOPSIS and AHP-MOORA) will help decision-makers to choose the best contractor alternative among others. The paper is organized as follows: Section 2 explores the previous studies which employed MCDM applications using AHP-TOPSIS and AHP-MOORA models. Section 3 describes the stages of contractor's section at Al-Quds University while section 4 illustrates the detailed procedure of each model under study. Section 5 shows numerical case study steps. Finally, the conclusions are drawn in the last section.

II. LITERATURE REVIEW

The decision-making process is no longer simple enough to choose between only two alternatives. Rather, the process has become more complex, as a decision must be taken according to multiple criteria that must be considered. Decision-making is now an issue left for expert consultation [2]. Hence the importance of multi-criteria decision-making techniques grow. In addition, decision-making is used by all layers of society. For example, decisions relating to our day-to-day activities, government, businesses, manufacturing, vaccine production, military and even space exploitation [2]. Another example, when the government wants to choose a company to operate a government institution, it needs to decide according to multiple criteria, and on the personal life issue, such as choosing a smartphone, the decision must be made according to multiple criteria such as price, quality, memory, etc. Scientists and specialists have been developed different MCDM techniques to facilitate the decision-making process [3]. The main idea of these techniques is to assess the compatibility of the available alternatives with the selection criteria considered by the decision maker, after that to rank the alternatives to choose between them. There has been interest in the applications of the AHP, TOPSIS, and MOORA techniques in different fields [4-10]. This section will cover five case studies of using these techniques in contractor selection area

MCDM Techniques Applications In Contractor Selection Area:

This section shows some of MCDM techniques applications in contractors selection field. Topcu, in 2004, proposed a model for selecting contractors in Turkey. The decision-making process in this model is divided into two main stages: (1) Contractor prequalification and (2) The choice of the eligible (compromised) bidder among prequalified contractors. As soon as the tender is intruding, the decision-making process begins by a supervisory committee that formed to select the contractor. The members of this committee set the criteria for decision-making. Then determine the weights of these criteria. One of the recommended methods for weighing decision-making criteria was AHP. Topcu suggested for future studies to improve this model, so it can be used in other countries and on a larger scale [11]. José Ramón San Cristóba [12] applied the two of MCDM techniques to select the contractor for the road building project "La Braguía" in the north of Spain. In this project, several important aspects and criteria were considered as the cost factor. The two techniques were used are the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods. The results showed that the same contractor have the highest ranking in the two methods [12]. Orkun and Nesrin [13] used the TOPSIS technique to analyze some contractors' selection criteria used in Turkey. The aim of this study was to determine the criteria that can be used for evaluation as well as price in the selection of contractors in public projects and to find out the importance of these criteria. To evaluate the criteria used, and to

determine the importance of each one, a survey was conducted to the construction department staff at the university. The staff evaluated 12 criteria for selecting contractors. The result of the study was different from what most believe that the criterion "Lowest Bid" is the most important in selecting contractors. In fact, it was the fifth criterion out of twelve. While the criterion "Termination of Construction Work" was the first and most important criterion based on the results of the study, and it means whether there is a termination in the previous works or not [13]. Armin [14] applied an integrated selection model for selecting the best contractor from five contractors. The model was a composite method of AHP and TOPSIS. The main objective of using AHP was to ranks the selection criteria and finds the relative importance of them. After using the AHP technique for ranking the selection criteria according to its importance. TOPSIS technique was used to rank the alternative contractors according to these criteria [14]. Fang *et al.* [15] developed an MCDM integrated FUZZY AHP (FAHP) and FUZZY TOPSIS (FTOPSIS) model for outcome-based contractors selection problems. The FAHP used to identify the importance weights of each criterion, and FTOPSIS used to obtain the performance ratings of the alternative contractors. AHP technique had some shortcomings as it uses an exact value and does not consider the uncertainty with human judgment to a number by linguistic. To overcome these shortcomings, the fuzzy AHP based on the fuzzy numbers was developed for solving with the uncertainty. The model makes it possible to combine qualitative and quantitative criteria to make a comprehensive judgment [15]. Another application of using integrated models of AHP-TOPSIS and AHP-MOORA for a real case study of contractor's selection will be given in the rest of this paper.

III. METHODOLOGY

The proposed methodology for selecting the contractor for Al-Quds University consists of three main stages as follows:

- *Preparation stage:* the required data will be collected for contractors' selection problem at Al-Quds University.

- *Design stage:* the proposed two integrated models will be formulated to solve the problem facing Al-Quds University based on the data collected. The models will consist of the following three successive steps: (1) identifying the evaluation criteria that considered as the most important performance measures for the contractors' selection for Al-Quds University, (2) Constructing the pairwise matrix for calculating the weights of these criteria using AHP technique, and (3) Conducting two integrated models which are: AHP-TOPSIS, and AHP-MOORA. as two scenarios to rank the contractors on hand.

- *Validation stage:* the proposed models will be examined using real data from Al-Quds University following by a comparison between the existing selection procedure and the proposed ones.

IV. OVERVIEW OF MCDM TECHNIQUES

As mentioned in the previous section, MCDM is a tool used to evaluate and choose alternatives between multiple conflict criteria when a decision is required. In this section, a list of different MCDM techniques will be demonstrated. In addition, the section will handle the concepts of three MCDM techniques which are: AHP, MOORA, and TOPSIS. These three techniques were selected as they are straightforward in computations and appropriate in use for the case of choosing the best contractor alternatives from others for Al-Quds University.

Analytic Hierarchy Process (AHP):

The Analytic Hierarchy Process (AHP) was developed by Saaty as a multi-criteria decision-making tool to organize and analyze complex decisions [16][17]. The AHP provides a way to decompose the problem into a hierarchy of sub-problems that are easier to grasp and subjectively evaluate. The subjective ratings are converted into numerical values and processed to rank each alternative on a numerical scale. the methodology of AHP can be explained in the following steps [18]:

Step #1:   The problem is decomposed into a hierarchy of goal, criteria, sub-criteria and alternatives. Hierarchy indicates a relationship between elements of one level with those of the level immediately below.

Step #2:   Data are collected from experts or decision-makers corresponding to hierarchic structure, in the pairwise comparison of alternatives on qualitative scale. The pairwise comparison matrix is developed using Saaty 1-9 preference scale as shown in the following Table 1.

Step #3:   The pairwise comparisons of various criteria generated at step 2 are organized into a square matrix. The diagonal elements of the matrix are 1. The criterion in the ith row is better than criterion in the jth column if the value of element (i,j) is more than 1; otherwise the criterion in the jth column is better than that in the ith row. The (j,i) element of the matrix is reciprocal of the (i,j) element.

Step #4:   The principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the relative importance of the various criteria being compared. The elements of the normalized eigenvector are termed weights with respect to the criteria or sub-criteria and ratings with respect to the alternatives.

Step #5:   The consistency of the matrix of order n is evaluated. Comparisons made by this method are subjective and the AHP tolerates inconsistency through the amount of redundancy in the approach. If this consistency index fails to reach a required level, then answers to comparisons may be re-examined. The consistency index (CI), is calculated as:

$$CI = (\lambda_{max} - n)/(n - 1) \qquad (1)$$

Where λ_{max} is the maximum eigenvalue of the judgement matrix. This CI can be compared with that of a random matrix, RI. The ratio derived, CI/RI, is termed the consistency ratio, CR. Saaty suggests the value of CR should be less than 0.1.

Step #6:   For rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings.

Table.1: Saaty's Pairwise Comparison Scale

Scale	Verbal judgment
9	Extremely important
7	Very strongly important
5	Strongly important
3	Moderately important
1	Equally important
2, 4, 6, 8	Intermediate value between adjacent scales
Reciprocals	Reflecting dominance of second alternative compared with the first

Order of Preference by Similarity to Ideal Solution (TOPSIS):

The Order of Preference by Similarity to Ideal Solution (TOPSIS) technique was developed by Yoon and Hwang in 1981 [5]. This method is used to select the best alternative among several alternatives and considering multiple criteria for selection. The main principle in this method is to choose the alternative closest to the positive ideal solution, and the furthest to the negative ideal solution [19].

In other words, the positive ideal solution is the one that increases the benefit criteria, which are the criteria that if the solution more agrees to, it is a good solution. In addition, the positive ideal solution

is reducing cost criteria, which are those criteria if the solution is less agrees to it, it is a good solution [20]. The steps of TOPSIS technique can be given as follows [10]:

Step #1:   The first stage includes the establishment of decision matrix (DM).

$$\mathbf{L_1} \qquad \mathbf{L_2} \qquad \dots \qquad \mathbf{L_n}.$$

$\mathbf{DM} = \begin{bmatrix} X_{ij} \end{bmatrix}$ here 'j' (j =1 2 3 4 5…. n) is the criteria index; 'n' denotes the number of potential sites available in the DM and 'i' refers to alternative index (i = 1 2 3 4 5 .... m). The elements $L_1, L_2 …. L_n$ denotes the different criteria while elements $C_1, C_2 …..C_m$ refers to alternative locations.

Step #2:   Calculation of Normalized Decision Matrix (NDM).   The NDM represents the relative performance of design alternatives.

$$NDM = R_i = x_{ij} \sqrt{\sum_{i=1}^{m} x_{ij}^2} \; / \tag{2}$$

Step #3:   Calculation of Weighted   Decision   Matrix (WDM).   The WDM is constructed by multiplying each element of column of (NDM) by their respective weights.

$$WDM = V = V_{ij} = w_j \times R_{ij} \tag{3}$$

Step #4:   Identify the positive ideal solution (A^*) and negative ideal solution (A^-), by using the following formulas:

$A^* = \{(\max v_{ij} \mid j \in J), (\min v_{ij} \mid j \in J')\}$.
$A^- = \{(\min v_{ij} \mid j \in J), (\max v_{ij} \mid j \in J')\}$.
(J = 1,2, 3, …, n)   J for the benefit criteria.
(J' = 1,2,3, …, n)   J' for the cost criteria.

Step #5:   Find the separation distance of each alternative from ideal and non-ideal solution.

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^* \right)^2} \quad i = 1,2, …, m \tag{4}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2} \quad i = 1,2, …, m \tag{5}$$

Where i = criterion index, j = alternative index.

Step #6:   Calculate the relative closeness of each location to the ideal solution, the relative closeness of the ith alternative with respect to.

A$_j$ is defined as: $C_i^* = S_i^- / \left(S_i^* + S_i^- \right)$ (6)

Where $0 \leq C_i^*$ 1 , i=1,2,…..,m

Step #7:   Rank the preferences order obtained or select the highest alternative among them. A set of different alternatives can be arranged in the descending order by the C_i^* alues from previous equation.

Multi-Objective Optimization on the basis of Ratio Analysis (MOORA).

Multi-Objective Optimization based on Ratio Analysis (MOORA) is one of MCDM techniques, which was developed by Brauers and Zavadskas [5]. It gives almost the same solution as TOPSIS technique [10], nevertheless, in this thesis we will use both techniques (TOPSIS and MOORA) with (AHP), to obtain multi solutions until, and so we have more options that we can compare between to obtain the optimal solution. MOORA technique is a method use to optimize converged solutions with multiple specific constraints and criteria. MOORA technique is effective and popular method for multi-criteria decision-making cases. It is considered easy and fast to implement. MOORA technique indicates a matrix of objectives alternatives, to which ratios are applied. Some of MOORA technique methods use comparison, in which a reference point is defined, and reach alternatives are compared with it [21]. Despite the difference in the basic principles in both TOPSIS and MOORA,

but the main goal of using these techniques is one, which is to make multi-criteria decision. Appling MOORA technique is done by following the next steps [22]:

Step #1:   Define the decision matrix with the alternatives and sets of criteria involved. (Equation 1)
MDF_{ij}

$$= \begin{matrix} A^1 \\ A^2 \\ \vdots \\ A^n \end{matrix} \begin{bmatrix} x_1^1 & \dots & x_K^1 & x_{K+1}^1 & \dots & x_{K+L}^1 \\ x_1^2 & \dots & x_K^2 & x_{K+1}^n & \dots & x_{K+L}^2 \\ \vdots & \dots & \dots & \dots & \dots & \dots \\ x_{12}^n & \dots & x_K^n & x_{K+1}^n & \dots & x_{K+L}^n \end{bmatrix}$$

Step #2:   Normalize the decision matrix. (Equation 2)

$$\left| \ddot{Y}_j \right| \quad \sqrt{\sum_{i=1}^{n} x_i^2} \tag{7}$$

Henceforward, the normalization of MDF_{ij} is calculated using the Equation 3

$$\xi_{ij} = \frac{x_{ij}}{\left| \ddot{Y}_j \right|} \tag{8}$$

Step #3:   Raise the weighted standard decision matrix (Equation 4)

$$T_{ij} = w_i \; \xi_{ij} \tag{9}$$

Step #4:   Proceed to determine the classification of the benefits criteria Equation (10) and the costs criteria Equation (11) respectively.

$$\sum_{i=1}^{g} T_i \tag{10}$$

$$\sum_{i=g+1}^{m} T_J \tag{11}$$

Step #5:   Calculate the contribution index β_i^- (12)

Step #6:   Establish the order of the alternatives.

V. IMPLEMENT THE PROPOSED MODELS AT AL-QUDS UNIVERSITY

The engineering office at Al-Quds University is the responsible for engineering projects, in terms of selecting the implementing agencies followed by supervising and investigating their work in the construction locations. The most important projects are the construction projects, where, like all institutions, the university relies on contractors to implement these construction projects. The current method of selecting contractors, at Al-Quds University, considers only one criterion, which is the lowest bid price. This makes the risk ratio, and the selection of the unsuitable contractor probability is very high. Also, this leads the university into legal or technical problems with contractors. Where the process of selecting contractors is a multi-criteria decision-making processes, the bid price is one of the criteria but may not be the most important. These criteria were not used at the Engineering Office at Al-Quds University. So, the concerned authorities such as the Palestinian Contractors Union has been contacted to obtain the official criteria for contractors' selection. There are several steps that decision makers must follow to be able to choose the appropriate contractor. Some of these steps are general like identify the project that will be implement while other steps specific to each proposed model separately.

Step.1) Identify the project to be implemented.

As a first step, decision makers must determine the nature of the project to be implemented. Such as defining the expected cost, filed of the project, requirements, limitations, and others.

Step.2) Identify the alternatives (contractor applications).

Through this step, the engineers in the engineering office, as decision makers, identify the contractors who have applied for the bid.

Step.3) Identify the main decision criteria and their attributes.

In this step, the criteria for selecting contractors are defined. These are the criteria by which contractors applying to implement the project are evaluated. In the case of Al-Quds University, the classification and evaluation criteria decided by the Palestinian Contractors Union and approved by the Ministry of Public Works and Housing in Palestine. These criteria are divided into five main criteria, which include several sub-criteria under them as shown in table 2.

Table.2: Criteria adopted by the Ministry of Public Works and Housing in Palestine for selecting contractors.

Criteria	symbol	Sub-criteria
Financial (F)	F1	Bank balance
	F2	Bid price
	F3	Equipment value
Legal (L)	L1	Contractors Association Membership
	L2	Environmental Protection Model Certification
	L3	Registered in the Ministry of Commerce
Technical (T)	T1	Experience of the engineering and technical staff
	T2	Suitable equipment for the project
	T3	Number of Workers
Experience (E)	E1	Number of projects completed
	E2	The value of completed projects
	E3	The field of completed projects
Management (M)	M1	Administrative restructuring
	M2	Qualified management staff
	M3	Administrative staff experience

Step.4) Select the proposed model for ranking the contractors.

In this step, the proposed models will apply using real data from Al-Quds University. Each one of these models is divided into two stages:

Stage#1: Criteria weighing.

 It is the stage of weighing the selection criteria. In this study, AHP technique was used to find the weights of the selection criteria.

Stage#2: Ranking the alternatives.

It is the stage the alternatives (contractors) are evaluated based on the selection criteria, to obtain a final ranking for the alternatives, so that the best alternative is chosen according to. In this study, TOPSIS and MOORA techniques were used to obtain a final rank of the alternatives.

Model#1: AHP_TOPSIS.

Technique - 1: *Analytic Hierarchy Process (AHP):*

- Step #1: The problem is decomposed into a hierarchy of goal, criteria, sub-criteria and alternatives.

- Step #2: develop the criteria pairwise comparison using Saaty 1-9 preference scale.

In this step, decision makers compare each criterion with the rest of the criteria at the same level. It should be noted that the contractor can only submit a bid if all legal conditions are met. If one of them is not met, the offer will not be accepted. Accordingly, neither the main legal criterion nor the legal sub-criteria were included in the comparison.

- Step #3: develop the criteria pairwise comparison matrix.

In this step a pairwise comparison matrix for main criteria and sub-criteria will be developed by arranging the values obtained in the previous questionnaire in the form of matrices, matrix for each group of criteria. For example, the following matrix is for main criteria group. By the same way all pairwise comparison matrices developed.

$$A_{main} = \begin{bmatrix} . & F & T & E & M \\ F & 1 & 1/3 & 1 & 5 \\ T & \ldots & 1 & 1 & 5 \\ E & \ldots & \ldots & 1 & 5 \\ M & \ldots & \ldots & \ldots & 1 \end{bmatrix}$$

- ep #4: normalized the pairwise comparison matrices.

This step is done by finding the sum of the values in each column, then dividing each value by the sum to find the values of the normalized pairwise comparison matrix elements. For example, in main criteria pairwise comparison matrix A_{main} the sum of first column values is: $(1+1/3+3+1+1/5) = 5.5333$, to normalized first value in the column, it is divided by 5.5333, $(1/5.5333=0.180722892)$. Using the same way to find the rest of the values in the matrix, the result normalized pairwise comparison matrix is as follow:

$$A_{main\ (norm)} = \begin{bmatrix} . & F & T & E & M \\ F & 0.181 & 0.11 & 0.290 & 0.249 \\ T & 0.542 & 0.33 & 0.29 & 0.294 \\ E & 0.181 & 0.33 & 0.29 & 0.294 \\ M & 0.036 & 0.066 & 0.058 & 0.059 \end{bmatrix}$$

the same way all matrices were normalized. After normalizing the matrix. To find the weight of each criterion, the summation of the values in the adjacent row to this criterion divided by the number of criteria in the matrix. For example, after normalizing the main criteria normalized pairwise comparison matrix, the summation of the values in adjacent row to the criterion (F) equal (1.147312994), so Criterion (F) weight = $1.147312994 / 5 = 0.229$, so, in all criteria. Then to find the overall weight for each criterion, multiply the main criterion with the weight of sub-criterion. For example, to calculate the overall weight of (F1) multiply it's weight by (F) criterion weight.

Overall weight of (F1) = (F1) weight * (F) weight

Overall weight of (F1) = 0.09 * 0.229 = 0.0206.

Table 3 show the weights and overall weight for the criteria and sub-criteria after normalizing the pairwise comparison matrices.

Table.3: The normalized criteria/sub-criteria weightings.

Criteria/sub-criteria	Level-one weight	Level-two weight	Overall weight
Financial	0.237	--	0.237
bank balance	--	0.09	0.021
Bid price	--	0.556	0.132
Equipment value	--	0.354	0.084
Technical	0.399	--	0.399
Experience of the engineering and technical staff	--	0.333	0.133
Suitable equipment for the project	--	0.333	0.133
Number of Workers	--	0.333	0.133
Experience	0.303	--	0.303
Number of projects completed	--	0.25	0.076
The value of completed projects	--	0.25	0.076
The field of completed projects	--	0.5	0.152
Management	0.061	--	0.061
Administrative restructuring	--	0.126	0.008
Qualified management staff	--	0.458	0.028
Administrative staff experience	--	0.416	0.025

- Step #5: evaluate the consistency of the matrices of order n.

At first calculate the maximum eigenvalue of the judgements matrix by finding the sum of the values of the column under the criterion, then multiplying them by the criterion weight.

After repeating this step for all criteria, the summation of the results is expressed as maximum eigenvalue (λ_{max}). Then λ_{max} was calculated by multiplying the weight of each criterion by the summation of the column under the criterion. For example, in main criteria pairwise comparison matrix, the summation of the column under (F) criterion = $(1+1/3+3+1+1/5) = 5.5333$, and (F) criterion weight = 0.299. to find λ_{max} multiply the column summation under F criterion by it weight, $(5.5333 * 0.299 = 1.27)$. In the same way for each criterion, so $\lambda_{max \ will}$ be:

$\lambda_{max} = 1.27 + 0.984 + 0.993 + 1.006 + 1.053 = 5.306$.

After that, to calculate the consistency index CI:

$CI = (\lambda_{max} - n)/ (n - 1) = $ $(5.306-5)/ (5-1) = 0.0766$.

Consistency ratio CR=CI/RI.   Where RI is a random index (1.12 for example).

CR=0.0766/1.12=0.07. (0.07) is Less than 0.1, so the judgements matrix is reasonably consistent.

By following the same steps, the consistency of all matrices checked. Table 4 shows the consistency ratio CR for all matrices.

Table.4: The CR for criteria/sub-criteria matrices.

matrix	λ_{max}	CI	CR	reasonably consistent (<0.1)
Main criteria	4.184	0.061	0.07	Yes
Financial sub-criteria	3.07	0.035	0.06	Yes
Technical sub-criteria	3	0	0	Yes
Experience sub-criteria	3	0	0	Yes
Management sub-criteria	3.011	0.006	0.01	Yes

- Step #6: rate each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion.

TOPSIS and MOORA techniques will be used to do this step.

Technique - 2: *Order of Preference by Similarity to Ideal Solution (TOPSIS):*

- Step #1: the establishment of decision matrix (DM).

To establishment the decision matrix (DM), the decision makers filled out the contractor evaluation form shown in Appendix (B) to evaluate each contractor. The information in the filled forms was arranged in a matrix, which is decision matrix (DM). Table 5 shows the decision makers evaluation for contactors considering the selection criteria.

Table.5: Decision maker's evaluation for contactors.

	F1	F2	F3	T1	T2	T3	E1	E2	E3	M1	M2	M3
	($)			(1 to 5) scale				($)		(1 to 5) scale		
C1	10000000	1034680	0.14	5	5	4	19	6000000	5	4	5	5
C2	11000000	906380	0.0795	4	3	4	15	2000000	3	3	2	4
C3	7000000	957186.81	0.1	4	2	3	14	3000000	3	3	3	4
C4	8000000	878095.3	0.92	3	2	1	9	1500000	3	2	2	2
C5	9000000	839127	0.1	4	1	3	13	2000000	3	2	3	3
C6	6000000	832271	0.087	3	1	1	10	900000	2	1	2	2

To establish the decision matrix (DM), the values in the table 5 must be arranged in a matrix.

- Step #2: Calculation of Normalized Decision Matrix (NDM).

To calculate the Normalized Decision Matrix (NDM), each value in the column is squared and then the resulting values are summed, and the square root of this sum is taken. Then each value in the column is divided by the square root of the sum. And so on to get all the values of the matrix

- Step #3: Calculation of Weighted Decision Matrix (WDM).

In this step, each value in the column under the criterion (x), for example, multiplied by the weight of the criterion (x) that was calculated by AHP technique, so WDM is:

	F1	F2	F3	T1	T2	T3	E1	E2	E3	M1	M2	M3
C1	0.010	0.061	0.012	0.070	0.100	0.074	0.043	0.061	0.094	0.005	0.019	0.015
C2	0.011	0.054	0.007	0.056	0.060	0.074	0.034	0.020	0.056	0.004	0.008	0.012
C3	0.007	0.057	0.009	0.056	0.040	0.055	0.032	0.030	0.056	0.004	0.011	0.012
C4	0.008	0.052	0.081	0.042	0.040	0.018	0.020	0.015	0.056	0.002	0.008	0.006
C5	0.009	0.050	0.009	0.056	0.020	0.055	0.029	0.020	0.056	0.002	0.011	0.009
C6	0.006	0.049	0.008	0.042	0.020	0.018	0.023	0.009	0.038	0.001	0.008	0.006

- Step #4: Identify the positive ideal solution (A*) and negative ideal solution (A-).

To identify the positive ideal value in each column the minimum value is desired in case of cost criteria such as bid price (F2), and the negative ideal is maximum value. And vice versa in the case of benefit criteria.

- Step #5: Find the separation distance of each alternative from ideal and non-ideal solution.

- Step #6: Calculate the relative closeness of each location to the ideal solution.

Table 6 shows the separation distance of each alternative from ideal and non-ideal solution and the relative closeness of each location to the ideal solution.

Table.6: the separation and relative closeness of each location to the ideal solution.

Contractor	S_i^*.		
C1	0.11204	0.14087	
C2	0.15301	0.05988	0.28128
C3	0.14516	0.06086	0.29541
C4	0.12074	0.12158	0.50173
C5	0.16497	0.03760	0.18563
C6	0.18237	0.03112	0.14578

- Step #7: final rank of the alternatives.

The alternatives are ranked according to C_i^* ()alue, where the one with the highest value is the best option. Table 7 shows the final rank of alternatives obtained from AHP-TOPSIS model.

Table.7: Final rank of alternatives obtained from AHP-TOPSIS model.

rank	alternative
1.	C1
2.	C4
3.	C3
4.	C2
5.	C45
6.	C6

Model#2: AHP_MOORA.

Technique#1: *Analytic Hierarchy Process (AHP):*

The steps of the AHP technique were applied and the resulting weights were presented in the previous AHP-TOPSIS model. These results will be used in the current model.

Technique#2: *Multi-Objective Optimization on the basis of Ratio Analysis (MOORA):*

- Step#1 to step#3 are the same way and results shown in TOPSIS technique in the previous AHP-TOPSIS model.

- Step #4: Proceed to determine the classification of the benefits criteria and the costs criteria.

In this step, for each alternative, all benefits criteria are summed together, and all cost criteria are summed together. All the criteria in this study is benefits expect bid price criterion (F2). So for each alternative all criteria are summed together expect (F2) criterion

- Step #5: Calculate the contribution index $\left(\beta_i^- \right)$

Table 8 shows the summation of benefits criteria and the summation of cost criteria and the contribution index β_i^- or each alternative.

Table.8: summation of benefits/ cost criteria and Contribution index β_i^- or each alternative.

Alternative	$\sum_{i=1}^{g} T_i$ benefits criteria)	$\sum_{i=g+1}^{m} T_J$ Cost criteria)	
C1	0.501852	0.06112	--
C2	0.341036	0.053541	0.287495
C3	0.311953	0.056542	0.255411
C4	0.297318	0.05187	0.245448
C5	0.277441	0.049568	0.227873
C6	0.177825	0.049163	0.128662

- Step #6: Establish the order of the alternatives.

The alternatives are ranked according to β_i^- ()alue, where the one with the highest value is the best option. Table 9 shows the final rank of alternatives obtained from AHP-MOORA model.

Table.9: Final rank of alternatives obtained from AHP-MOORA model.

rank	alternative
1.	C1
2.	C2
3.	C3
4.	C4
5.	C5
6.	C6

Step.5) Is the rank given by all models the same?

Through the results in the previous step. The ranks given by all models is not the same, so go to step 6. Otherwise, go to step 8.

Step.6) Calculating the correlation coefficient between rankings models.

In this step, the correlation between obtained ranks has been checked. To determine which models will be used in the selection process. This is done by using Spearman's rank correlation coefficient (ρ) [23]. The correlation coefficient (ρ) between each two models was calculated. Using the following equation:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}. \qquad (13)$$

Where di = xi – yi, is the difference between ranks.

To calculate the correlation coefficient (ρ) between the ranks obtained from AHP-TOPSIS and AHP-MOORA models, find the difference (di) between the ranks, then use it in correlation coefficient (ρ) calculation. Table 10 shows the difference calculation.

Table.10: difference calculation between the two ranks.

AHP-TOPSIS	AHP-MOORA	d_i^x .	
C1	C1	0	

C4	C2	2	4
C2	C3	-1	1
C3	C4	-1	1
C5	C5	0	0
C6	C6	0	0
		sum	6

Using the equation (13): $\rho = 1 - \dfrac{6(10)}{6(6^2-1)}\ 0.82857$

Step.7) choose the best rank.

Since the correlation coefficients between the two models is high, the best rank is the average between the obtained ranks. Table 11 shows the obtained average rank (final rank).

Table.11: Average rank (final rank).

AHP-TOPSIS	AHP-MOORA	Average rank	Adjust rank
1	1	1	1
4	2	3	3
2	3	2.5	2
3	4	3.5	4
5	5	5	5
6	6	6	6

Step.8) Raise a recommendation to choose the best alternative to implement the project.

In this step, the final rating is raised to the decision makers, with a recommendation to choose one of the first three alternatives. Here, the final decision will be made considering what was previously mentioned criteria for choosing the best alternative.

VI. RESULTS AND DISCUSSION

Contractors at Al-Quds University are selected based on only one criterion, which is the lowest bid price. This process neglecting the rest of the standards, whether technical, legal, management and others that affects the quality of the project, the time of its implementation, and other problems. While when using the proposed method, which includes two different MCDM models for, which considered multiple criteria (financial, legal, technical, experience, and administrative), find that the obtained rank of contractors differs from the one obtained from the current method used in university. Table 12 shows the ranks obtained from the current method and the proposed method.

Table.12: Ranks obtained from the current method and the proposed method.

Current Method		Proposed Method	
Contractor	Rank	Contractor	Rank
C1	6	C1	1
C2	4	C2	3
C3	5	C3	2
C4	3	C4	4
C5	2	C5	5
C6	1	C6	6

The previous results were discussed with the engineer responsible for approving the final decision in the contractor selection process at Al-Quds University. Where the engineer clarified that the decision maker has the right to choose a contractor other than the contractor with the lowest bid price for considerations other than the bid price, especially if one of the contractors outperforms than contractor with the lowest bid price, especially in the technical aspect. Considering that the difference in the price between the two contractors must not be more than 15% of the price of the lowest bid price.

To obtain an alternative that fulfills the selection criteria mentioned previously, at the same time its bid price does not exceed the lower bid price by 15%, the increase percentage in the bid price of the first three alternatives in final proposed rank was calculated, by dividing the different between each alternative bid price and the minimum bid price, then divide the obtained different by the minimum bid price. The percentages of increase were as shown in table 13.

Table.13: First Three Alternatives' Percentages of Increase.

A	bid price	min bid price	different	% of increase
C1	1034680	832271	202409	24%
C2	906380	832271	74109	9%
C3	957186.81	832271	124915.81	15%

VII. CONCLUSION

The engineering office at Al-Quds University consider only one criterion for selecting contractors to implement the university's projects. This increases the possibility of additional costs to correct errors during construction and after construction, especially when maintaining. These errors result from using an inappropriate process for selecting contractors. To solve this problem, a more accurate process has to be used to select the contractors in the Engineering Office at Al-Quds University, which is the main objective of this study.

In the decision-making process, all aspects of the construction project must be considered, whether cost, time, and quality. One of the best ways to decide several factors is MCDM techniques. MCDM techniques are many and varied. In addition, have many uses in different fields. Through the literature review, three techniques were selected to be used in this thesis (AHP, TOPSIS, and MOORA). It was chosen because these models are uncomplicated, easy to apply and have direct calculations. It also serves the decision-making process, both in determining the importance of each of the selection criteria compared to the other criteria on the one hand and evaluating the available alternatives according to these criteria and arranging them from best to worst so that the final decision is made through this resulting arrangement on the other hand.

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