International Journal of Scientific & Engineering Research, Volume 14, Issue 1, January, 2023
ISSN 2229-5518

Evaluation and Selection of Contractors for Petroleum Projects in Egypt Using Multi Criteria Decision Making (MCDM) Techniques

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Abstract

Selection of the best-value contractor is pivotal to all industries, especially those involving various stakeholders and costing billions of dollars. The best-value contractor is defined as the one that can achieve the perfect combination of requirements that ensure the successful implementation of the project within a realistic cost and acceptable quality. Although it may incur extra costs, to the owners, due to reworks and incomplete project scope, the lowest bid method has been adopted for awarding project contracts in the Egyptian market, especially in the public sec-tor. The oil and gas industry is the lifeblood of industrialized nations; hence, successful delivery of the complete project scope according to the required standards and technical specifications is extremely crucial. Investigation of the best-value contractor selection approaches within the oil and gas market has been scarcely discussed in the literature. The current study fills this knowledge gap by employing multi-criteria decision-making (MCDM) techniques to provide a decision support tool for contractor selection within the Egyptian oil and gas sector. The MCDM techniques include the analytical hierarchy process (AHP); the technique of order preferences by similarity to the ideal solution (TOPSIS); the weighted sum method (WSM); and the weighted product method (WPM). The study has been deployed on two actual petroleum sector projects in Egypt. The results confirm that the AHP technique provides a significant benefit by considering the individual preferences of all decision-makers (i.e., bidding committee members when weighting the criteria) mitigating the drawbacks of the existing methodologies. The results also confirm that MCDM techniques of TOPSIS, WSM, and WPM have captured all the decision-makers' preferences of bidders where the best-qualified bidder is the one achieving the required combination of requirements to execute the contract. In conclusion, MCDM techniques provide an advantage over the lowest bid strategy as they provide a valuable tool to decision-makers to select best-value contractors.

Key Words: Contractor selection, Bid evaluation, Tender evaluation, Contractors' evaluation criteria, Multiple-criteria decision making, Tender evaluation criteria, Petroleum projects in Egypt, TOPSIS, AHP, WSM, WPM.

1 Introduction

1.1 Background

The Oil and Gas Industry is a multimillion-dollar industry. The companies which are involved in the Oil and Gas industry are well aware of the cost factor which plays a very critical part in every industry. Generally, the importance of proper monitoring of a project and its application will ensure project success. In fact, the main issues of project management, i.e., the cost, time and quality, have become the main cause in measuring the success of project management over the years. So, selecting the best contractor for petroleum projects is very crucial as quality and standards will be the major factor alongside with cost and revenue. Tendering and bidding are the trading method internationally recognized and widely adopted in assigning or undertaking engineering tasks. Bid evaluation is not only the key link of bidding, but also the soul of the entire bidding activity. But the question is how we can compare between these contractors which in this case can be called alternatives. Actually, comparing between more than one alternative to choose the best one from our point of view might be challenging in so many ways. What we need to do first is to decide on our criteria of selection "what is our goal?". For example, we can compare between contractors based on their past experience related to similar projects other criteria could be the financial statement, workload, equipment list, legal documents [1]. Bid evaluation is used to denote the procedure for strategic assessment to tender bids submitted by pre-qualified contractors. The strategy used for bid evaluation should reflect the client's objectives [2] [3].

The lowest bid method has been adopted to award the contracts especially for public projects in Egypt. The first priority for many owners is to choose the lowest price during bidding phase which is not always the best decision to accomplish the complete work scope. In some cases, it may incur the owner extra costs due to rework. When it comes to oil and gas industry, accomplishment of the complete scope of work with the required technical specifications and global standards is very crucial and this can be due to the fact that oil is the lifeblood of the industrialized nations and has a great direct impact on the environment, industry and national economy and security as well. The process of bidder's selection mainly goes through two steps. The first one is to choose the criteria and the criteria weights for the evaluation of bidders. The second step is evaluating the bidders based on their submitted proposals according to the weights assigned per each evaluation criteria. Both steps are implemented by the responsible bidding committee members. Members are responsible for assigning the weights and also for the evaluation of bidder's bids. One of the main problems, while implanting the process of assigning weights to the evaluation criteria is that certain members lead the discussion of assigning the weights from of course their point of view, work experience and knowledge, other members may feel uncomfortable to express their opinions, knowledge and experience [4].

1.2 Scope and Objective of The Study

The scope of this work mainly revolves around investigating the multi criteria decision making techniques like the analytical hierarchy process (**AHP**), technique of order preferences by similarity to the ideal solution (**TOSPSIS**), the weighted sum method (**WSM**), and the weighted product method (**WPM**) to enhance the bidding and selection phase in the oil and gas industry in Egypt through applying the prementioned methods to the bidder's selection process in two real case studies ,since this process is considered to a multi criteria decision making problem. Not only that but also to mitigate leading the discussion of assigning the evaluation criteria and their corresponding weights to certain committee members, members with

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ISSN 2229-5518

higher influence, through allowing all members to express themselves and participate in the process of assigning weights to the evaluation criteria of bidders.
The main purpose of the study is to explore more advance techniques or methods that can be utilized to find the best contractor based on our needs and requirements for the petroleum sector in Egypt, a contractor who optimizes all requirements and approaches the ideal case of achieving all the required criteria, according to its weights, when compared to other contractors. This will help to choose the best value contractor to achieve the required quality within the estimated budget with a highly skilled manner. Also, this study will help to represent the personal opinion of each committee member and also reflect the experience and knowledge of each member during selecting the best bidder mitigating the drawbacks of the old selection methods by expressing the personal opinion without the influence of any other external factors that may influence the process. The findings of this study will help project managers, tender evaluators working in the petroleum sector in Egypt to construct their own model with their requirements, needs and specifications with the desired weights and significance of their required criteria to choose between different bidders, awarding the most qualified bidder who achieves the combination of the exact required qualifications.

2 Literature Review

2.1 Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a technique developed by Saaty [5] to help decision makers choose the best alternative among a set of many other alternatives. AHP is a systematic method of organizing the alternatives and giving them priorities based on the free judgment of the decision maker, those judgements can be tangible or in tangible qualitative or quantitative factors, through comparing the alternatives using Saaty Scale of relative importance a final priority will be given to the alternatives based on the decision maker judgement.

Intensity	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Moderate importance	Experience and judgment slightly favor one over the other.
5	Strong importance	Experience and judgment strongly favor one over the other.
7	Demonstrated importance	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolute importance	The evidence favoring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values between two adjacent judgment	When compromise is needed.
Reciprocal	While comparing reversely one risk to other, value would be 1/original comparison.	
If the criteria in the column is preferred to the criteria in the row, then the inverse of the rating should be assigned.		

Table 1. Saaty Scale of Relative Importance [5]

The AHP has also been applied to many other areas in construction management such as determination of facility location and proposal evaluation for public contract (M. Balubaid and R. Alamoudi) [6]. Wei- Chin Wang [7] have utilized the AHP in real two case studies in Taiwan to support the best value contractor, through these two case studies, this work confirms that the AHP provides a significant benefit for considering the individual preferences of all decision-makers when weighting the criteria. However, this study finds two major potential obstacles, the legal requirements associated with using the AHP and the time it takes to implement the AHP. To overcome these obstacles, this work suggests guidelines to meet the legal requirements for implementing the AHP in the BV contractor selection, and proposes several strategies to shorten the AHP implementation time.
MCDM can be applied in all the areas of research and selection in the fields of management, manufacturing, planning, education, transportation, construction, logistic, medical, control and agriculture. MCDM is used in these areas for selection, ranking and evaluation [8].
One of the major difficulties facing researchers who tried to utilize the AHP for alternative selection is time to construct the pairwise matrices and to illustrate the idea behind AHP to others, so many attempts by researchers to adapt the AHP to take less time and to mitigate the reassessment cycle (C.-C. Lin, W.-C. Wang) [9] [10].

2.1.1 AHP Implementation Steps

2.1.1.1 Hierarchy Structure

The decision maker has to develop the hierarchy structure which consists of the main levels of hierarchy. Level one is the goal of the process which in our case is choosing the best qualified contractor. The second level is the main criteria of evaluation upon which the decision making is choosing between the different alternatives (the Bidders). The intermediate levels are the sub-criteria per each main criterion defined by the decision maker. And the last level is the alternatives. It can be seen in the following figure 1 and figure 2.

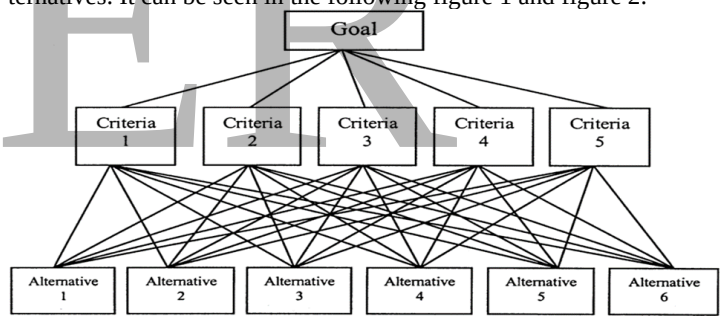

Figure 1. General Hierarchy Structure for AHP [6].

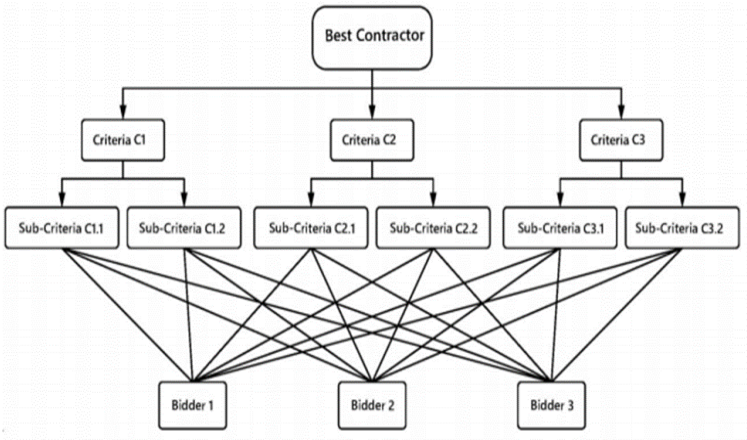

Figure 2. Selection of Bidders Using AHP [12]

2.1.1.2 Developing the Pair Wise Matrices

After developing the hierarchical structure with the main goal, criteria, sub criteria and at the final level the list of the alternatives, the pair wise matrices are to be developed. First the decision maker

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ISSN 2229-5518

needs to assign weights to the proposed criteria upon which he/she will decide the best alternative meeting his/her requirements. So, a pair wise comparison matrix to be developed to compare between the different criteria using Saaty 9-point Scale of relative importance. In order to assign priority weights to those criteria. A normalized decision-making matrix to be developed using any kind of normalization preferably (linear normalization). Then a comparison between the alternatives input for each criterion is to be developed to assign overall priority for the alternatives thus having a final priority rank with the best alternatives.

2.1.1.3 CONSISTENCY CHECK

To ensure that the data entered by the decision maker is consistent, a consistency check is done to check how consistent the inputs of the decision maker are. The consistency is checked by calculating the consistency ratio and must be less than **0.10**.

Example (1) -Given by the Author

Three Alternatives A, B and C.
A decision maker

- prefers A to B so A>B.
- prefers B to C so B>C.
- So, if he/she prefers A to C A>C this will be consistent judgment.
- If he prefers C to A C>A this will be in consistent judgment.

However, we shall not force the consistency as inconsistency is a part of the human judgment

Example (2)-Given by the Author

- A>B has value of 3>1
- B>C has value of 5>1
- So, A>C doesn't necessarily have the exact value of 15>1 but might be 9>1 because too much consistency is not realistic as we are dealing with human judgments.

Prof. Saaty [5] gave a measurement for the consistency using the consistency index (**CI**) as deviation or a degree of the consistency and is given as a function of the maximum eigenvalue (**λ_{max}**) and the size of the square matrix (n).

$$CI = \frac{\lambda_{max} - n}{n-1}$$

Knowing the consistency index **(CI)** the next question how do we use this index. Again prof. Saaty proposed that we use this index by comparing it with what is called the random consistency index (**RI**)
Saaty randomly generated reciprocal matrix using his scale and got the random consistency index. The average random consistency index of sample size 500 matrices is shown in the following table

Size of matrix	1	2	3	4	5	6	7	8
Index (RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41

Table 1. Random Consistency Index by Saaty.

Then Saaty proposed what is called the consistency ratio (CR) which is a comparison between the consistency index and consistency ratio which can be calculated using the following equation. If the value of the consistency ratio is less than 10% then the judgement inconsistency is acceptable if the consistency ratio is more than 10% the judgement inconsistency is not acceptable and judgment must be revised.

$$CR = CI/CR$$

2.1.1.4 MAIN ADVANTAGES OF AHP

The advantages of AHP over other multi criteria methods are its flexibility, intuitive appeal to the decision makers and its ability to check inconsistencies (Ramanathan 2001) [11]. Generally, users find the pairwise comparison form of data input straightforward and convenient.

- Its usability.
- It is an effortlessly reasonable system.
- It does not require authentic information sets.
- The structure of AHP yields a simple route for a scholastic individual to take care of complex issues.[12]

Additionally, the AHP method has the distinct advantage that it decomposes a decision problem into its constituent parts and builds hierarchies of criteria. Here, the importance of each element (criterion) becomes clear (Macharis et al. 2004) [13]
AHP helps to capture both subjective and objective evaluation measures. While providing a useful mechanism for checking the consistency of the evaluation measures and alternatives, AHP reduces bias in decision making. (Anything objective sticks to the facts, but anything subjective has feelings. Objective and subjective are opposites. Objective: It is raining. Subjective: I love the rain!)
AHP is uniquely positioned to help model situations of uncertainty and risk since it is capable of deriving scales where measures ordinarily do not exist (Millet & Wedley 2002) [14].

MAIN DRAWBACKS OF AHP

The artificial limitation of the use of the 9−point scale. Sometimes, the decision− maker might find difficult to distinguish among them and tell for example whether one alternative is 4 or 5 times more important than another. Also, the AHP method cannot cope with the fact that alternative A is 100 times more important than alternative B. The AHP-method can be considered as a complete aggregation method of the additive type. The problem with such aggregation is that compensation between good scores on some criteria and bad scores on other criteria can occur. Detailed, and often important, information can be lost by such aggregation.
With AHP the decision problem is decomposed into a number of subsystems, within which and between which a substantial number of pairwise comparisons need to be completed. This approach has the disadvantage that the number of pairwise comparisons to be made, may become very large, and thus become a lengthy task [13]
Many researchers have long observed some cases in which ranking irregularities can occur when the AHP or some of its variants are used. This rank reversal is likely to occur e.g., when a copy or a near copy of an existing option is added to the set of alternatives that are being evaluated. Triantaphyllou [31] proved that rank reversal is not possible when a multiplicative variant of the AHP is used. According to Belton (1986) [15] a key issue for the AHP ranking reversals is the interpretation of the criteria weights. However, the AHP and some of its variants are considered by many as the most reliable MCDM method.
A major drawback which can be visualized in almost all the techniques of MCDM is that the assignment of the weight is a voluntary choice, it not only requires profound insight rather the assignment need to be quite accurate (accuracy itself is a voluntary entity and may differ from problem to problem and situation to situation)

2.2 TECHNIQUE FOR ORDER OF PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS)

The Technique for Order of Preference by Similarity to Ideal Solution TOPSIS is a multi-criteria decision analysis method, which was originally developed by Ching-Lai Hwang and Yoon in 1981 [16] with further developments by Yoon in 1987, and Hwang, Lai and Liu

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ISSN 2229-5518

in 1993 [17].
TOPSIS is a decision-making technique. is a goal-based approach to find the closest alternative to the ideal solution. This method evaluates options based on the ideal solution Similarity. An option is graded higher if it resembles or similar to the ideal solution.
The ideal solution is in every way the best that doesn't really exist, and TOPSIS technique tries to find the alternative that comes close to the ideal solution. Basically, for measuring similarity of an alternative (or option) to ideal level and non-ideal, we consider distance of that option from ideal and non-ideal solution [18] [19] [20]. TOPSIS method has been used and implemented for supplier selection (P. Wangchen Bhutia) [21]. And been widely used for other studies to identify the optimal machining condition with reduced particle emission during machining of the Al-Si based 1%SiC reinforced nanocomposite material (V. Pandey and K. Chakraborty) [22], and other studies to evaluate sustainable human resource management in the manufacturing Companies (P. Saeidi, A. Mardan) [23].
TOPSIS method has also been used in a wide variety in the engineering fields in general like: -

- (S. Koundinya and S. Seshadri) [24] explored selection of refringent for industrial heat pumps
- Selection of safety system for urban rail stations (H.-W. Wu, E. Li, Y. Sun, and B. Dong) [25]
- Assessment of red tide risk – Environmental pollution [26]

TOPSIS has been commonly used for MCDM and based on comparing all alternatives and deciding the best one which will have the shortest distance (Euclidean distance from the ideal solution). Vector normalization is done to compare between alternatives then get weighted normalized decision matrix with the help of AHP. Eventually we calculate the ideal best and ideal worst alternative and Euclidean distance from ideal best and worst for each alternative after that we will be able to get the performance score for each alternative (Highest score is the best alternative).

2.2.1 General TOPSIS Process with Seven Steps Is Listed Below

Step (1)
Form the decision matrix D as follows [16]: -

$$\begin{pmatrix} A1 & X11 & X12 & X1j & X1n \\ A2 & X21 & X22 & X2j & X2n \\ Aj & Xj1 & Xj2 & Xjj & Xjn \\ Am & Xm1 & Xm2 & Xmj & Xmn \end{pmatrix}$$

Where,

A_i = i^{th} alternative bidders

X_{ij} = the numerical outcome of the i^{th} alternative bidders with respect to j^{th} criteria.

Step (2)
Normalize the decision matrix D by using the following formula:

$$r_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{n} x_{ij}^2}$$

Step (3)
Construct the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights calculated earlier by the seven committee members using AHP (Analytical Hierarchy Process) [18] [21] [27].
The weighted normalized value vij is calculated as:

$$v_{ij} = w_j r_{ij}$$

Step (4)
Determine the positive ideal solution and negative ideal solution.

$$A^* = \{(\max v_{ij} \mid j \epsilon J), (\min v_{ij} \mid j \epsilon J')\}$$

$$A^- = \{(\min v_{ij} \mid j \epsilon J), (\max v_{ij} \mid j \epsilon J')\}$$

J = 1,2, 3…., n
where J is associated with the beneficial criteria like quality of a product
J' = 1,2, 3…., n
where J' is associated with the non-beneficial criteria like the price of the product
Step (5)
Calculate the separation measure.
The separation of each alternative from the positive ideal one is given by:

$$S_j^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}$$

where i = 1, 2…, m
Similarly, the separation of each alternative from the negative ideal one is given by:

$$S_j^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

Step 6
Calculate the relative closeness to the ideal solution.
The relative closeness of Ai with respect to A* is defined as:

$$C_j^* = S_j^- / (S_j^* + S_j^-)$$

$$0 \leq C_j^* \leq 1$$

where i = 1, 2…, m

The larger the C_j^* value, the better the performance of the alternatives (Bidders).

Main Advantages of TOPSIS Method

- It is simple to use.
- It takes into account all types of criteria (subjective and objective).
- It is rational and understandable.
- The computation processes are straight forward.
- The concept permits the pursuit of best alternatives criterion depicted in a simple mathematical calculation

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MAIN DRAWBACKS OF TOPSIS METHOD

This technique uses crisp information which is impractical in many real-world situations because decision makers usually express opinions in natural language such as Poor and Good. Information in the form of natural language, i.e. words, in turn is characterized by fuzziness and uncertainty (i.e. 'what is the meaning of poor').[28]
The whole process should be redone if one of the alternatives is deleted or another alternative is added to the set.

2.3 WEIGHTED SUM MODEL (WSM)

The weighted sum model (WSM) also called weighted linear combination (WLC) or simple additive weighting (SAW), is one of the simplest techniques in MCDM techniques and is considered to be the earliest technique for decision making problems that enable users to select between different alternatives and is suitable for simple problems and criteria of a well-defined numerical values. WSM allows the comparison of the alternatives by assigning scores, and then using these scores, standard values are generated for the alternatives under consideration. So, overall, the results are in the form of good, better and best. The criteria are given weights depending on the severity of each; sum of all these weights must be 1. Each alternative is assessed with respect to every attribute (S. S. Goswami - N. Caterino, I. Iervolino - E. Triantaphyllou) [29] [30] [31]. WSM Weighted sum model is another model for selection after assigning weights of each criteria-on and doing vector normalization we multiply the weights of each criterion by the normalized vector getting weighted normalized decision matrix then based on summation of each criterion for one alternative we can get our preference score the choosing the highest to be our best selection.

2.3.1 GENERAL WSM PROCESS WITH STEPS

Step (1)
Form the decision matrix D as follows [16]: -

$$\begin{pmatrix} A1 & X11 & X12 & X1j & X1n \\ A2 & X21 & X22 & X2j & X2n \\ Aj & Xj1 & Xj2 & Xjj & Xjn \\ Am & Xm1 & Xm2 & Xmj & Xmn \end{pmatrix}$$

Where,
Ai = i^{th} alternative bidders
X_{ij} = the numerical outcome of the i^{th} alternative bidders with respect to jth criteria.
Step (2)
Normalize the decision matrix D by using the following formula:

- For beneficial criteria.

$$r_{ij} = x_{ij}/maximum(x_j)$$

- For non-beneficial criteria.

$$r_{ij} = minimum(x_j)/\, x_{ij}$$

Step (3)
Construct the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights calculated earlier by the seven committee members using AHP (Analytical Hierarchy Process) . The weighted normalized value v_{ij} is calculated as:

$$v_{ij} = w_j r_{ij}$$

Step (4)
Calculate the performance score per each alternative by taking the sum values of the weighted normalized values v_{ij} per each i^{th} alternative (bidder).
Performance score per each i^{th} bidder can be calculated using the below formula.

$$A_i^{WSM} = \sum_{j=1}^{n} w_j\, r_{ij}$$

Alternative -Bidder with the highest performance score is considered to be the best alternative.

2.4 WEIGHTED PRODUCT MODEL (WPM)

Weighted Product model is another model for selection after assigning weights of each criterion and doing vector normalization. we get the weights of each criterion to be the power of normalized vector getting weighted normalized decision matrix then based on multiplication -product of each criterion for one alternative we can get our preference score then choosing the highest to be our best selection. (S. S. Goswami - N. Caterino, I. Iervolino - E. Triantaphyllou) [29] [30] [31].
Weighted product model WPM is the extension of the weighted sum model WSM with differences. The main difference is that instead of addition in the main mathematical operation, there is multiplication. The same steps of WSM are applied regarding the normalized decision matrix, the big differences are: -

- When, assigning the criteria weights to the develop the weighted normalized decision matrix, in WSM we multiply the criteria weight by the normalized element to get the weighted normalized value v_{ij}, while in WPM the normalized value v_{ij} is calculated by raising the normalized element to the power of the corresponding criteria weight. The steps are shown below.
- To get the performance score of alternatives in WSM, we add the weighted normalized values v_{ij} per each i^{th} alternative (bidder), while in WPM we multiply instead of addition.

2.4.1 GENERAL WPM PROCESS WITH STEPS LISTED BELOW

Step (1)
Form the decision matrix D as follows [16]: -

$$\begin{pmatrix} A1 & X11 & X12 & X1j & X1n \\ A2 & X21 & X22 & X2j & X2n \\ Aj & Xj1 & Xj2 & Xjj & Xjn \\ Am & Xm1 & Xm2 & Xmj & Xmn \end{pmatrix}$$

Where,
Ai = i^{th} alternative bidders
X_{ij} = the numerical outcome of the i^{th} alternative bidders with respect to i^{th} criteria.
Step (2)
Normalize the decision matrix D by using the following formula:

- For beneficial criteria.

$$r_{ij} = x_{ij}/maximum(x_j)$$

- For non-beneficial criteria.

$$r_{ij} = minimum(x_j)/\, x_{ij}$$

Step (3)

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ISSN 2229-5518

Construct the weighted normalized decision matrix by raising elements of the normalized decision matrix to the power of its associated weights calculated earlier by the seven committee members using AHP (Analytical Hierarchy Process). The weighted normalized value v_{ij} is calculated as:

$$v_{ij} = r_{ij}^{w_j}$$

Step (4)
Calculate the performance score per each alternative by multiplying values of the weighted normalized values v_{ij} per each i^{th} alternative (bidder).
Performance score per each i^{th} bidder can be calculated using the below formula.

$$A_i^{WPM} = \prod_j^n r_{ij}^{w_j}$$

Alternative -Bidder with the highest performance score is considered to be the best alternative.

3 Selection procedures and requirements

3.1 Letter of Invitation (LOI)

The letter of invitation is sent to a certain shortlisted contractor inviting them to submit a proposal for a consulting assignment. The LOI includes a list of all shortlisted firms to whom similar letters of invitation are sent, and a reference to the selection method and applicable guidelines or policies of the financing institution that governs the selection and award process.

3.2 Tender Documents

The tender documents are the documents including the technical details and full requirements regarding the scope of work and required specifications and other technical details. It also states the methodology required when submitting technical and commercial offers, the evaluation criteria and also the pricing tables. Tender documents can be considered as the constitution for all invited bidders. It also includes the proposed draft contract that all bidders must stick to.

3.3 Standards Forms of Contract

Selection of contractors is very essential to the success of the project so during the bidding phase the contractor is ordered to submit proposals based on two main types of contracts for large or complex projects a Time-Based Contract and a Lump-Sum Contract.

3.4 Time Based Contract

This type of contract is appropriate when it is difficult to define or fix the scope and the duration of the services, either because they are related to activities carried out by others for which the completion period may vary, or because the input of the contractors required for attaining the objectives of the assignment is difficult to assess. In time-based contracts the contractor provides services on a timed basis according to quality specifications, and Contractor's remuneration is determined on the basis of the time actually spent by the Contractor in carrying out the Services and is based on (i) agreed upon unit rates for the Contractor's experts multiplied by the actual time spent by the experts in executing the assignment, and (ii) reimbursable expenses using actual expenses and/or agreed unit prices. This type of contract requires the Client to closely supervise the Contractor and to be involved in the daily execution of the assignment.

3.5 Lump Sum Contract

This type of contract is used mainly for assignments in which the scope and the duration of the Services and the required output of the Consultant are clearly defined. Payments are linked to outputs (deliverables) such as reports, drawings, bill of quantities, bidding documents, or soft-ware programs. Lump-sum contracts are easier to administer because they operate on the principle of a fixed price for a fixed scope, and payments are due on clearly specified outputs and mile-stones. Nevertheless, quality control of the Consultant's outputs by the Client is paramount.

3.6 Bidders' Selection

3.6.1 Quality Based Selection (QBS)

The selection between different contractors is based on quality and is called quality-based selection (QBS). The top ranked contractor is invited to negotiate the contract. If Financial Proposals were invited together with the Technical Proposals, only the Financial Proposal of the technically top-ranked Consultant shall be opened by the Contracting Entity. All other Financial Proposals are returned unopened after the Contract negotiations are successfully concluded and the Con-tract is signed. The second top ranked bidder is considered to be an alternative offer to be taken into consideration in case there is no agreement has been reached with the first top ranked bidder. This procedure is upon contractor approval.
It must be taken into consideration that the final proposed prices by contractor shall not exceed the client estimated budget by 25% - 30% or a restudy by client should be done and of course retendering shall take place.
Quality and Cost Based Selection (QCBS)
The selection between different contractors is based on quality and cost and is called quality-cost based selection (QCBS). Bidders in this particular case were invited to participate in this tender by submitting one envelope for both technical and financial offers, so that the prices are shown directly with the technical offer. It should be noted in QCBS in other cases the bidders may submit the offers in two separate envelopes, After the technical evaluation is completed, the Contracting Entity shall notify those Consultants whose Proposals were considered non-responsive that their Financial Proposals will be returned unopened after completing the selection process and Contract signing. The Contracting Entity shall simultaneously notify in writing those Consultants that have achieved or surpassed the minimum overall technical score and inform them of the date, time and location for the opening of the Financial Proposals. The opening date should allow the Consultants sufficient time to make arrangements for attending the opening. The Consultant's attendance at the opening of the Financial Proposals is optional.
In this case both technical and commercial offer shall be evaluated at the same time, and the price will be taken as a main evaluation criterion for bidders.

3.6.2 Fixed Budget Selection (FBS)

The budget of the project is indicated in the tender documents, and any bidder exceeding the stated budget will be disqualified. The highest rank technical proposal will be the selected.

3.6.3 Least-Cost Selection

The contractor with the minimum accepted technical score will be

International Journal of Scientific & Engineering Research, Volume 14, Issue 1, January, 2023
ISSN 2229-5518

selected.

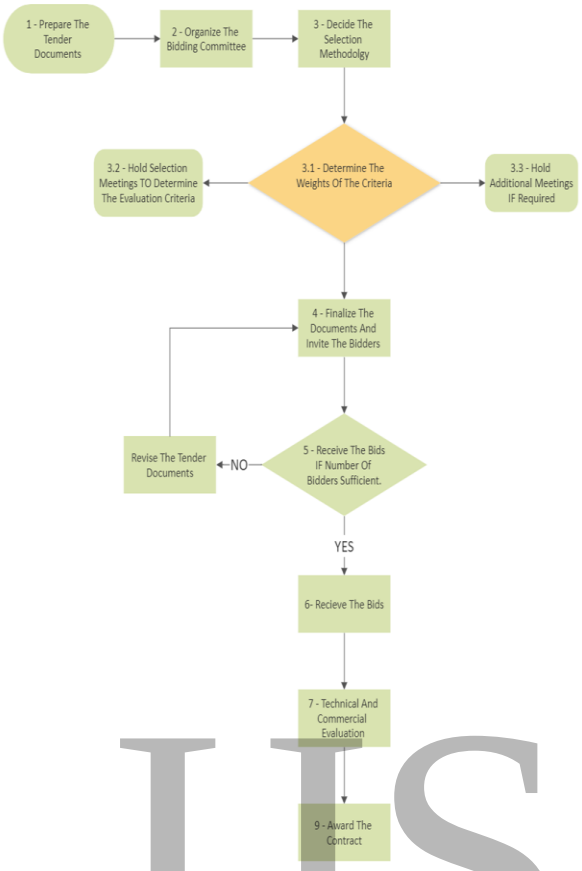

Figure 1. Selection of Bidders.

4 Methodology

To enhance the process of selecting the best value contractor for petroleum projects in Egypt, this study main goal is to gain information and experience through applying the MCDM, multi criteria decision making techniques just as, the analytical hierarchy process AHP, technique of order preferences by similarity to the ideal solution TOPSIS, weighted sum method WSM and weighted product method WPM to the evaluation process of contractors for two projects within the petroleum sector in Egypt to provide a decision support tool for contractor selection. comparing between different contractors based on relative importance of a predetermined criteria. It should be highlighted that the case studies used are only for educational purposes to gain experience by exploring the Multi Criteria Decision Making Techniques.

4.1 Research Method

Analytical Hierarchy Process AHP, Technique for order preference by similarity to the ideal solution TOPSIS, Weighted Sum Model WSM and Weighted Product Model WPM are introduced to bidding committee members for one of the petroleum companies in Egypt, with full details and information gathered, using Literature review for MCDM different techniques and studied tenders. (See previous chapters). In order to determine and chose the best Bidder, the MCDM techniques were applied to real case studies for two going tenders, just for educational purposes.

All committee members have participated in two main processes: -

- Determining the evaluation criteria and its relative weights through applying AHP.
- Evaluation of Bidders based on their submitted proposals using AHP for first case study and other techniques (TOPSIS, WSM and WPM) for the second case study.
- A taskforce of engineers also participated in the process of evaluation of the technical and commercial proposals of bidders

4.2 Research Tools

Required data and information for the selection procedures have been collected and mathematical models are generated using: -

- Microsoft Excel.
- Octave GNU - MATLAB.
- Smath Studio.

4.3 Data Analysis

The qualitative and quantitative data was used during the data analysis and was prepared in the most suitable format using the most well-organized and valuable technique. The quantitative data collected was presented in form of tables and percentages. The qualitative data was presented in form of figures and texts. Then, analysis was carried out on the data and the results presented in tables.

4.4 Research Challenges

- To make the committee members fully understand the idea of MCDM.
- Time limitations therefore, excel sheets and codes are generated to accelerate the process.
- The process required a lot of accuracy from committee members for data entry.
- A lot of people were involved during the evaluation phase

5 First Case Study

In this case study, the Analytical Hierarchy Process AHP has been investigated and utilized to be used for technical evaluation of proposed bidders. The scope of project is about site survey and rig positioning services “on call out basis”. The contract duration is set to be two years with one optional additional year. This contract is time-based contract. The selection between different contractors is based on quality and is called quality-based selection (QBS). The top ranked contractor is invited to negotiate the contract. If Financial Proposals were invited together with the Technical Proposals, only the Financial Proposal of the technically top-ranked Consultant shall be opened by the Contracting Entity. All other Financial Proposals are returned unopened after the Contract negotiations are successfully concluded and the Con-tract is signed. Scope of work is about predrilling geo surveys, investigation and offshore jack-up drilling rig moves.

5.1 Members of the selection committee

When the tender document of the project was almost complete, bidding committee was established. A 7-member bidding committee consist of: - Three expert technical members from the concerned offshore department. Two expert members from the procurement and contracts department. One expert member from the health, safety and environment HSE department. One expert member from the finance and planning department. All of the members are qualified with a minimum 18 years of experience and BSc degree in engineering.

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5.2 Decision Criteria

After the committee was established, meetings were held to determine the evaluation criteria. Based on previous experiences and studied tenders with same scope of work, the bidding committee decided on a three-level hierarchy the first level is the main objective of the committee which is the selection of the best technically accepted contractor the second level of hierarchy is the main evaluation criteria which are: -

1. Bidder Past Performance and Track Record.
2. Technical Specifications
3. Safety and Quality Performance.
4. Bidder's Structure and Organization.
5. Bidder's Financial Credentials.

The third level of hierarchy is sub-criteria and is considered as shown if figure 4.

5.3 The Process of Determining Weights of Criteria

The AHP method was implemented based on decision criteria displayed in Fig.4 The committee members have implemented the AHP method

Description of the process

In AHP weightings, the relative importance of criteria in the same level is compared to obtain PWMs using the 9-value scale by Saaty. Shown in the following figure, seven members (three from the technical offshore department, one from HSE and QA department, one from Finance and Planning department and two members from Contracts and Procurement department) in the committee assessed the AHP weights. Each member completed six relative importance assessment tables and, thus, generated six PWMs: one level-one PWM; Five level-two PWMs (Past Performance, Technical, HSE-QA, Organization and financial credentials. In total, 42 (= 6×7) PWMs are acquired. This the total number of matrices required without checking the consistency. A check is made to check the consistency ratio is less than 0.10. if not a recalculation of the matrices is done. Full Steps for the process can be seen in the following figure.

Each committee member has to compare between the main evaluation criteria using the AHP method. This is done in one pair wise comparison matrix. With help of Saaty scale. After implementing this step, the main criteria weights will be assigned to the main evaluation criteria. The second step, using the AHP, the committee member has to compare between the sub-criteria of each main criterion, then assign local weight for each sub-criterion. Based on the global weight of the main criterion which is already calculated in step-1, the global weight of each sub-criterion will be calculated by multiplying the local weight of the sub-criterion calculated from step-2 by the global weight of the corresponding main criterion calculated from step-1. After implementing this step, scores for each criterion have been assigned. The final criteria scores were obtained by taking the average score per each criterion and sub-criterion for each committee member.

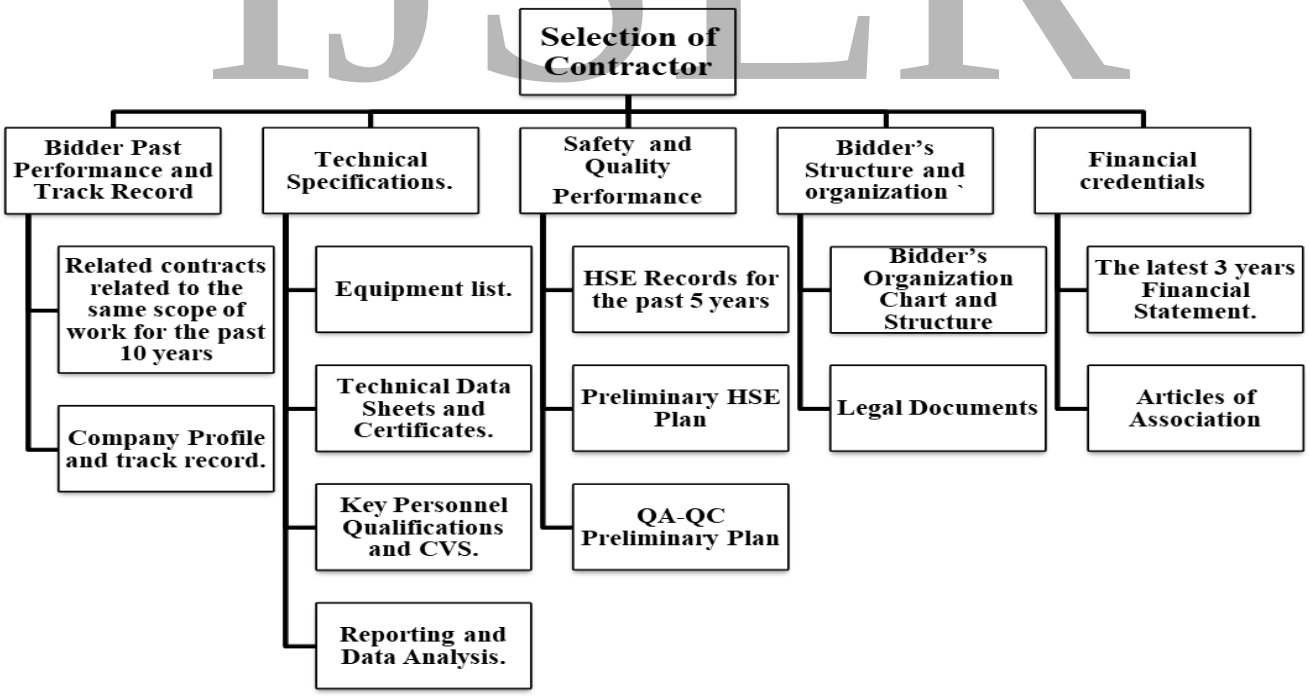

Figure 2. Evaluation Criteria Hierarchy Using AHP

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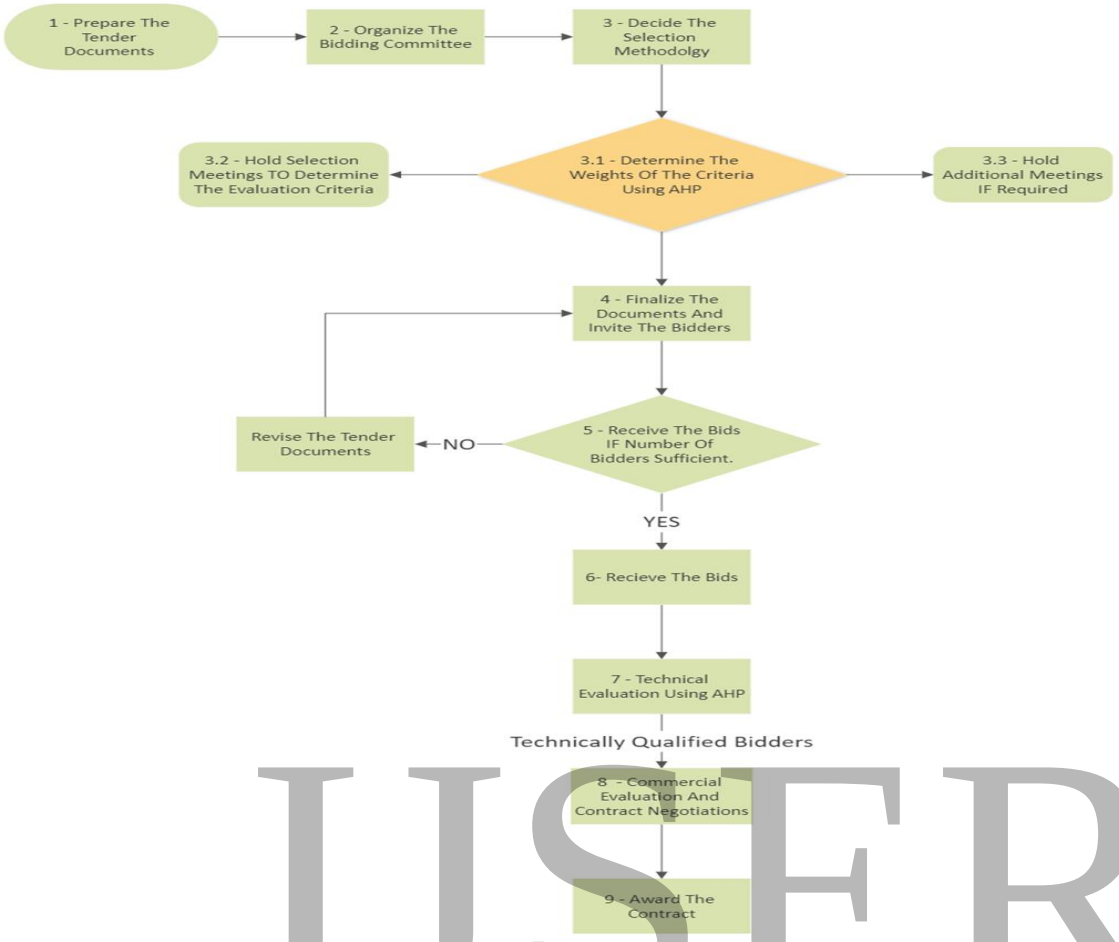

Figure 5. Bidders' Selection Process Using AHP

Criteria- Members	M1-T	M2-T	M3-T	M1-F&P	M1-HSE-QA	M1-C&P	M2-C&P	Overall, Criteria Weight
Past Experience Track record	**0.300**	**0.153**	**0.224**	**0.089**	**0.221**	**0.112**	**0.127**	**0.175**
Related contracts	0.258	0.131	0.192	0.080	0.166	0.101	0.114	0.149
Company Profile	0.043	0.022	0.032	0.009	0.055	0.011	0.013	0.026
Technical specifica-tions	**0.305**	**0.350**	**0.352**	**0.495**	**0.558**	**0.431**	**0.454**	**0.421**
Equipment list	0.183	0.136	0.137	0.071	0.337	0.045	0.053	0.137
Technical Data	0.033	0.056	0.056	0.071	0.096	0.024	0.030	0.052
Personnel	0.016	0.029	0.029	0.165	0.029	0.209	0.227	0.101
Reporting	0.074	0.130	0.131	0.188	0.095	0.153	0.144	0.131
Safety and Quality	**0.302**	**0.392**	**0.247**	**0.303**	**0.087**	**0.279**	**0.218**	**0.261**
HSE Records	0.219	0.287	0.181	0.216	0.070	0.214	0.164	0.193
HSE Plan	0.058	0.051	0.032	0.043	0.011	0.041	0.037	0.039
QA-QC Plan	0.025	0.054	0.034	0.043	0.007	0.024	0.016	0.029
Bidder's structure	**0.043**	**0.051**	**0.091**	**0.069**	**0.080**	**0.082**	**0.109**	**0.075**
Bidder Organization Chart	0.038	0.043	0.076	0.062	0.064	0.008	0.011	0.043
Legal Documents	0.005	0.009	0.015	0.007	0.016	0.074	0.098	0.032
Financial Credentials	**0.049**	**0.054**	**0.085**	**0.044**	**0.054**	**0.096**	**0.093**	**0.068**
Financial statement	0.039	0.043	0.068	0.040	0.027	0.077	0.074	0.052
Articles of Association	0.010	0.011	0.017	0.004	0.027	0.019	0.019	0.015

Table 3. Weights of The Evaluation Criteria and Sub-criteria.

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5.3.1 Pair-Wise Comparison Matrices and Consistency Checks

All mathematical calculations have been done using software (OCTAVE GNU and EXCEL). The consistency of the matrices has been calculated for each pair-wise comparison matrix to mitigate the errors that may occur. The results are accepted as long as the consistency ratio is less than 0.10. For sure and due to human error, the consistency ratio isn't less than 0.10 for all matrices and members had to reassign the values for the pairwise matrix to reach a value less than 0.10 to make sure that their choices are consistent and their judgement will be truly expressing their point of view. See the following table

Assessment Cycle	First	Second	Third
No. of PWMS performed	42	17	5
No. and % of unacceptable PWMs	17 (40%)	5 (29%)	0 (0%)
Total PWMS	42 + 17 + 5 = 64 PWMS		

Table 4. Assessment Cycle for The Weighting Process.

All members have participated in the process of assigning the weights for the main criteria, and their corresponding sub-criteria. We can say now that this process has a reasonable weight that can represent the personal opinion of each committee member and also reflect the experience and knowledge of each member during selecting the best bidder. Actually, this step has mitigated the drawbacks of the old selection methods by expressing the personal opinion without the influence of any other external factors that may influence the process. During the old-fashioned methods when assigning the weights (if any). Any committee member is entitled to make personal recommendations regarding the weights to be used at committee meetings. If none of the members object, a final criteria weight will be chosen. Unfortunately, because the criterion weightings are frequently compromised when some committee members predominate the talks, this method is criticized for not fully capturing all opinions for the criteria weightings by the individual committee members. The fairness of the selecting procedure may therefore be questioned. In order to address this critique, this study looks for a new approach—the AHP—to support the process of weighing criteria.

5.3.2 Analysis

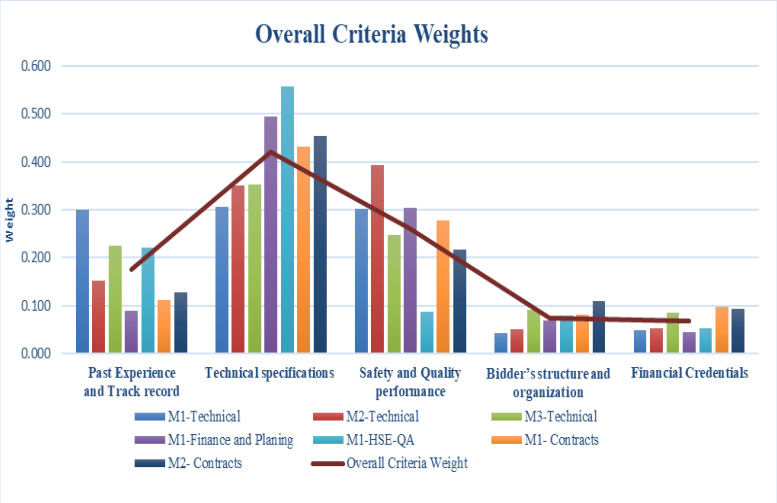

Figure 6. Weights of The Evaluation Criteria and Sub-criteria.

Figure 6 and Table 4 shows the results of the global criteria weights for all bidding committee members

- **The technical specifications** criterion got the highest global weight of **0.421** as a main criterion which indicates the relative importance of that criterion and its corresponding sub criteria for that particular project when compared to other criteria. It can be seen that all members have put the highest priority weight to the technical specifications as an evaluation criterion.
- The second priority overall weight of **0.261** is given to the **safety and quality performance.**
- **Past Experience and Track record** main criterion got **0.175** as an overall weight.
- **Bidder's structure and organization** main criterion got **0.075** as an overall weight.
- **Financial Credentials** main criterion got **.068** as an overall weight.
- **Total weight of criteria = 0.421 + 0.261 + 0.175 + 0.075 + 0.068 = 1.**

It can be seen that all the three members from the technical department have given the technical specification and safety and quality performance criteria the highest weights of an average weight of 0.336 and 0.314 respectively which reflects their priorities for the project. Also, the past performance and track record criteria has been given a reasonable average weight of 0.226 for the three members.

Bidder's structure and organization and Financial Credentials criteria has been given an average weight of 0.062 for the three members which represents a less priority for those criteria for the technical department.

It can be seen that all the two members from the contracts and procurement department and the member from the finance and planning have given the technical specification the highest priority weight, an average of 0.460 for the three members, although they don't have the enough experience nor knowledge when it comes to the detailed technical specifications. Which actually represents the fact that human mind tends to exaggerate the unknown as this is not their area of expertise, they have put a higher weight to this creation when compared to other weights for other criteria.

They have given Safety and quality performance criterion an average weight of 0.266 and an average weight of 0.109 for Past Experience and Track record criterion. Bidder's structure and organization criterion has been given an average weight of 0.087 for the three members and Financial Credentials has been given an average of 0.078. it can be noted that those members have given a less weights for the financial credentials, past experience and organization of the bidder although these are their area of expertise (they are responsible for evaluating this part of the bidders) and this may proof that people tend to exaggerate what they are not fully aware of at the expense of the criteria they are fully aware of.

It can be seen that the member from HSE and Quality department has given the technical specification the highest priority weight of 0.558 which reflects the priority of this criterion for that member as it may contains critical details for the implementation of the project.

Safety and quality performance criterion have been given a weight of 0.087 which is less than the anticipated from this member. Which might be explained, as this member is the key expert when it comes

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to this particular evaluation criterion and tends to give other priorities for other criteria

Past Experience and Track record has been given weight of 0.221. Bidder's structure and organization criterion has been given weight of 0.08. Financial Credentials main criterion has been given weight .054. Past Experience and Track record main criterion got 0.175 as an overall weight. Related contracts with the same scope of work the past 10 years got a total overall global weight of 0.149 = 85% of the weight of the corresponding main criterion. Company Profile and track record got a total overall global weight of 0.026 = 15% of the weight of the corresponding main criterion.

The technical specifications main criterion got the highest global weight of 0.421 as a main criterion. Equipment list got a total overall global weight of 0.137 = 33% of the weight of the corresponding main criterion. Technical Data Sheets and Certificates got a total overall global weight of 0.052 = 12% of the weight of the corresponding main criterion. Personnel Qualifications and CVS got a total overall global weight of 0.101 = 24% of the weight of the corresponding main criterion. Reporting and Data Analysis got a total overall global weight of 0.131 = 31% of the weight of the corresponding main criterion.

Safety and Quality performance main criterion got an average overall weight of 0.261 as a main criterion. HSE Records for the past 5 years got a total overall global weight of 0.193 = 74% of the weight of the corresponding main criterion. Preliminary HSE Plan got a total overall global weight of 0.039 = 15% of the weight of the corresponding main criterion. QA-QC Preliminary Plan got a total overall global weight of 0.029 = 11% of the weight of the corresponding main criterion.

Bidder's structure and organization main criterion got an average overall weight of 0.075 as a main criterion. Bidder's Organization Chart got a total overall global weight of 0.043 = 57% of the weight of the corresponding main criterion. Legal Documents got a total overall global weight of 0.032 = 43% of the weight of the corresponding main criterion. Financial Credentials main criterion got an average overall weight of 0.068 as a main criterion. Bidder's latest 3 years financial statement got a total overall global weight of 0.052 = 77% of the weight of the corresponding main criterion. Articles of Association got a total overall global weight of 0.015 = 23% of the weight of the corresponding main criterion.

5.4 Bidders' Evaluation Process.

In order to define a minimum qualification for bidders' selection, a hypnotical bidder was generated named B-Min. The B-Min bidder is generated to represent the personal judgement of the committee members to express the minimum qualifications that the bidder needs to be qualified to win the contract, so that when the member is using the AHP pair wise comparison matrices ,to compare between the different bidders, will consider the minimum qualification during the comparison of the bidders and think of what the minimum qualified bidder should have and compare this idea to the real proposed bids by other bidders. Eventually, the scores (final Priority vectors) of bidders will be obtained and. For sure, all bidders with score higher than the minimum bidder B-min will be qualified and the highest score will be invited to negotiate the contract. any bidder less than the minimum bidder score will not be able to negotiate the contract in case of any failure to award the contract to the highest score bidder. If now bidder fulfill a score higher than the minimum bidder B-Min, which means that all bidders haven't achieved the minimum requirements to be awarded, the tender will be cancelled.

Description of the evaluation process

1. Each committee member has to compare between the bidders based on the suggested evaluation criteria using the AHP method. This is done for each sub criterion in a pair wise comparison matrix, with help of Saaty scale After implementing this step, priority vector of bidders for each criterion will be obtained from each member participating in the evaluation process.
2. The second step, using the pre-assigned criteria weights calculated form the weighting process using the AHP, an overall priority vector of bidders is obtained, for each criterion, by multiplying the criterion priority vector of bidders **by** the pre assigned global weight of the criterion calculated in the weighting process.
3. The final priority vector of bidders for each evaluation criterion is obtained by taking the average score per each criterion for all committee members. The final results can be found on the following tables.

Analysis of The Bidders' Evaluation Process

A final score for each bidder is obtained by taking the average score for each criterion for all members participated in the evaluation process. Now we have a final score for each criterion for each bidder based on members input, thus a total score for each bidder for all criteria can be calculated by adding those criterion scores to have a final score for each bidder. we can find out that the winner is Bidder-3 as it has the highest criteria total score when com-pared to other bidders. The following tables shows the results and the final qualified bidder.

As shown in the next tables. The following: -

- Bidder-Min got a score of 23.877
- Bidder-1 got a score of 19.718
- Bidder-2 got a score of 26.641
- Bidder-3 got a score of 29.763

From the previous results of bidders, it can be concluded that bidder-1 is less than minimum hypothetical bidder, meaning that this bidder is permanently disqualified, as it doesn't have the combination of qualifications that meets the minimum requirements to be awarded of the project contract.

If this contract is QCBS- quality and cost-based selection. Both Bidders Bidder-2, and Bidder-3 would have been technically qualified and selection will be based on their prices presented in their commercial offers. Bidder-3 and bidder-2 got a final score more than the minimum bidder, meaning that both bidders are fully qualified to be awarded. But since this contract is a quality-based selection contract QBS, only the bidder with highest technical overall final score is invited to negotiate the contract and to be awarded upon completion.

We also need to keep in mind that in case of failure to negotiate the contract with the bidder with the highest technical score, the bidder with the second highest technical score is invited instead as long as it is technically accepted and fulfills the minimum qualifications (In other words having a score more than the B-Min). If this contract is QCBS- quality and cost-based selection. Both Bidders Bidder-2, and Bidder-3 would have been technically qualified and selection will be based on their prices presented in their commercial offers.

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B-1 Scores	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Final Score
Past Experience and Track record								**0.041**
Related contracts	0.034	0.032	0.038	0.041	NV	0.033	0.034	0.035
Company Profile	0.011	0.005	0.003	0.004	NV	0.005	0.005	0.006
Technical specifications								**0.092**
Equipment list	0.028	0.052	0.054	NV	0.061	NV	NV	0.049
Technical Data	0.023	0.013	0.017	NV	0.005	NV	NV	0.015
Personnel	0.014	0.015	0.005	NV	0.029	NV	NV	0.016
Reporting	0.026	0.007	0.007	NV	0.013	NV	NV	0.013
Safety and Quality								**0.036**
HSE Records	0.019	0.028	0.017	NV	0.017	NV	NV	0.0.02
HSE Plan	0.007	0.008	0.014	NV	0.013	NV	NV	0.010
QA-QC Plan	0.003	0.009	0.003	NV	0.005	NV	NV	0.005
Bidder's structure								**0.017**
Organization Chart	NV	NV	NV	0.012	NV	0.020	0.012	0.015
Legal Documents	NV	NV	NV	0.002	NV	0.001	0.003	0.002
Financial Credentials								**0.012**
Financial statement	NV	NV	NV	0.010	NV	0.011	0.009	0.010
Association	NV	NV	NV	0.002	NV	0.002	0.002	0.002
Final Score x 100								**19.718**

B-2 Scores	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Final Score
Past Experience and Track record								**0.021**
Related contracts	0.020	0.018	0.021	0.020	NV	0.014	0.012	0.018
Company Profile	0.002	0.003	0.003	0.004	NV	0.003	0.005	0.003
Technical specifications								**0.130**
Equipment list	0.059	0.028	0.024	NV	0.035	NV	NV	0.036
Technical Data	0.013	0.013	0.007	NV	0.010	NV	NV	0.011
Personnel	0.040	0.051	0.053	NV	0.029	NV	NV	0.043
Reporting	0.055	0.030	0.020	NV	0.052	NV	NV	0.040
Safety and Quality								**0.074**
HSE Records	0.083	0.028	0.072	NV	0.027	NV	NV	0.052
HSE Plan	0.007	0.008	0.014	NV	0.004	NV	NV	0.008
QA-QC Plan	0.015	0.008	0.018	NV	0.015	NV	NV	0.014
Bidder's structure								**0.013**
Organization Chart	NV	NV	NV	0.010	NV	0.004	0.012	0.009
Legal Documents	NV	NV	NV	0.006	NV	0.003	0.005	0.005
Financial Credentials								**0.028**
Financial statement	NV	NV	NV	0.025	NV	0.020	0.025	0.023
Association	NV	NV	NV	0.005	NV	0.005	0.004	0.005
Final Score x 100								**26.642**

Table 5. Assigned Scores to Bidders.

B-3 Scores	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Final Score
Past Experience and Track record								**0.097**
Related contracts	0.083	0.090	0.071	0.072	NV	0.093	0.091	0.083
Company Profile	0.011	0.016	0.017	0.013	NV	0.016	0.012	0.014
Technical specifications								**0.119**
Equipment list	0.039	0.049	0.054	NV	0.033	NV	NV	0.044
Technical Data	0.013	0.013	0.026	NV	0.009	NV	NV	0.015
Personnel	0.040	0.019	0.033	NV	0.029	NV	NV	0.030
Reporting	0.039	0.017	0.053	NV	0.013	NV	NV	0.030
Safety and Quality								**0.033**
HSE Records	0.008	0.028	0.008	NV	0.035	NV	NV	0.020
HSE Plan	0.013	0.008	0.006	NV	0.006	NV	NV	0.008
QA-QC Plan	0.006	0.009	0.003	NV	0.005	NV	NV	0.006
Bidder's structure								**0.024**
Organization Chart	NV	NV	NV	0.016	NV	0.016	0.012	0.015
Legal Documents	NV	NV	NV	0.006	NV	0.014	0.009	0.010
Financial Credentials								**0.023**
Financial statement	NV	NV	NV	0.015	NV	0.019	0.015	0.016
Articles of Association	NV	NV	NV	0.006	NV	0.006	0.007	0.007
Final Score x 100								**29.763**

B-Min Scores	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Final Score
Past Experience and Track record								**0.016**
Related contracts	0.012	0.010	0.019	0.016	NV	0.008	0.011	0.013
Company Profile	0.003	0.002	0.003	0.004	NV	0.002	0.005	0.003
Technical specifications								**0.080**
Equipment list	0.012	0.008	0.005	NV	0.008	NV	NV	0.008
Technical Data	0.004	0.013	0.002	NV	0.028	NV	NV	0.012
Personnel	0.008	0.015	0.010	NV	0.014	NV	NV	0.012
Reporting	0.011	0.077	0.051	NV	0.052	NV	NV	0.047
Safety and Quality								**0.118**
HSE Records	0.083	0.110	0.097	NV	0.114	NV	NV	0.101
HSE Plan	0.013	0.016	0.006	NV	0.015	NV	NV	0.013
QA-QC Plan	0.005	0.003	0.005	NV	0.005	NV	NV	0.005
Bidder's structure								**0.020**
Organization Chart	NV	NV	NV	0.005	NV	0.003	0.006	0.005
Legal Documents	NV	NV	NV	0.017	NV	0.013	0.015	0.015
Financial Credentials								**0.005**
Financial statement	NV	NV	NV	0.003	NV	0.003	0.004	0.003
Articles of Association	NV	NV	NV	0.001	NV	0.001	0.002	0.002
Final Score x 100								**23.877**

Table 6. Assigned Scores to Bidder-Min

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Main Criterion	Sub-Criteria - Bidders	B1	B2	B3	B-Min
Past Experience and Track record	Related contracts	0.0352	0.0175	0.0833	0.0127
	Company Profile	0.0055	0.0033	0.0140	0.0034
Technical specifications	Equipment list	0.0486	0.0364	0.0437	0.0084
	Technical Data	0.0145	0.0107	0.0152	0.0117
	Personnel	0.0156	0.0432	0.0299	0.0118
	Reporting	0.0130	0.0395	0.0304	0.0474
Safety and Quality performance	HSE Records	0.0201	0.0522	0.0197	0.1008
	HSE Plan	0.0103	0.0081	0.0081	0.0125
	QA-QC Plan	0.0050	0.0138	0.0055	0.0045
Bidder's structure and organization	Bidder Organization	0.0147	0.0087	0.0145	0.0049
	Legal Documents	0.0021	0.0046	0.0098	0.0153
Financial Credentials	financial statement	0.0096	0.0233	0.0162	0.0031
	Articles of Association	0.0023	0.0046	0.0066	0.0015
Final Score		0.19718	0.26642	0.29763	0.23877

Table 7. Final Assigned Priority Scores to Bidders.

Main Criteria Scores	Bidder-1	Bidder-2	Bidder-3	Bidder-Min
Past Experience and Track record	4.082	2.096898	9.73959	1.615781
Technical specifications	9.189	12.991517	11.940833	7.959415
Safety and Quality performance	3.557	7.417234	3.345763	11.796695
Bidder's structure and organization	1.688	1.333061	2.445562	2.031605
Financial Credentials	1.202	2.802902	2.291455	0.473831
Final Score	19.71786	26.64161	29.76320	23.87733

Table 8. Final Assigned Priority Scores to Bidders for Main Criteria.

Main Criteria Scores	Weight (%)	Bidder-1	Bidder-2	Bidder-3	Bidder-Min
Past Experience and Track record	17.5%	4.082	2.096898	9.73959	1.615781
Rank of the criterion		2	3	1	4
Technical specifications	42.1%	9.189	12.991517	11.940833	7.959415
Rank of the criterion		3	1	2	4
Safety and Quality performance	26.1%	3.557	7.417234	3.345763	11.796695
Rank of the criterion		3	2	4	1
Bidder's structure and organization	7.5%	1.688	1.333061	2.445562	2.031605
Rank of the criterion		3	4	1	2
Financial Credentials	6.8%	1.202	2.802902	2.291455	0.473831
Rank of the criterion		3	1	2	4
Final Score		19.71786	26.64161	29.76320	23.87733
Final Rank		4	2	1	3

Table 9. Final Rank of Bidders for Main Criteria.

The previous table shows the final results of bidders for each main criterion and the overall final score. It also shows the rank of bidders per each main criterion.

Past Experience and Track record.

This highest score for that criterion is Bidder-3.

The least score for that criterion is Bidder-Min.

Technical specifications.

This highest score for that criterion is Bidder-2.

The least score for that criterion is Bidder-Min

Safety and Quality performance.

This highest score for that criterion is Bidder-Min.

The least score for that criterion is Bidder-3.

Bidder's structure and organization.

This highest score for that criterion is Bidder-3.

The least score for that criterion is Bidder-2.

Financial Credentials.

This highest score for that criterion is Bidder-2.

The least score for that criterion is Bidder-Min.

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ISSN 2229-5518

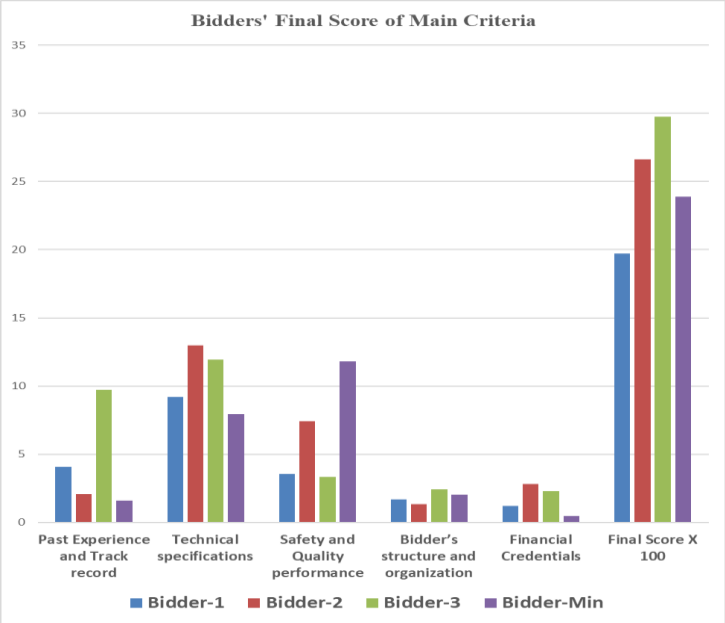

Figure 7. Bidders Priority Scores.

It can be seen from above figures and tables that Bidder-3 is the highest score and is the winning bidder as this bidder achieves the combination of qualifications that meets the committee member criteria and it is noted that this bidder only got the first rank in two main criteria of past performance and track record and the criteria of structure and organization. These two criteria represent an aggregate weight of 25%. And also got the 4th rank in safety and quality criterion which represents a weight of 26.1%. While Bidder-2 also go the first rank in also two main criteria of technical specifications and financial credentials criteria. These two criteria represent an aggregate weight of 48.9% which is nearly two times the weight of the criteria that Bidder-3 got first rank in. Bidder-2 got the 4th rank in structure and organization criterion which represents 7.5%. The previous table shows that Bidder-3 has got a much higher scores than Bidder-2 when it comes to past experience and track record related to the same scope of work for the contract. And also, a slightly higher scores for structure and organization. So, Bidder-2 may work on the past experience and related record for that scope of work in order to compete with Bidder-3 at the time of renewal of the contract. Actually, after trying re-mathematical calculations again with (if Bidder-3 were only 55% of the score been given or assigned to the main criterion of past performance and track record of Bid-der-3) Bidder-2 could have been awarded the contract. This actually shows the power of Analytical Hierarchy Process (AHP) to capture all the commit-tee members opinions and experience when it comes to weighting of evaluation criteria and the process of bidder's evaluation. Bidder-3 has achieved the required combination of different qualifications to be invited to negotiate the contract and be the successful bidder

All mathematical calculations have been done using software (GNU Octave and Microsoft Excel 2019). The consistency of the matrices has been calculated for each pair-wise comparison matrix to mitigate the errors that may occur. The results are accepted as long as the consistency ratio is less than 0.10. For sure and due to human error, the consistency ratio isn't less than 0.10 for all matrices and members had to reassign the values for the pairwise matrix to reach a value less than 0.10 to make sure that their choices are consistent and their judgement will be truly expressing their point of view. Tables shows the number of rechecks and PWMS.

Assessment Cycle – Weighting Process	First	Second	Third
No. of PWMs performed	42	17	5
No. and % of unacceptable PWMs	17 (40%)	5 (29%)	0 (0%)

Assessment Cycle – Evaluation Process	First	Second	Third
No. of PWMs performed	52	15	2
No. and % of unacceptable PWMs	15 (28.8%)	2 (14%)	0 (0%)

Assessment Cycle – Total Processes	First	Second	Third
No. of PWMs performed	94	32	7
No. and % of unacceptable PWMs	32 (34%)	7 (22%)	0 (0%)
Total PWMs	94 + 32 + 7 = 133 PWMS		

Table 10. Assessment Cycle for The Process.

6 Second Case Study

In this case study, the Analytical Hierarchy Process AHP has been utilized and used in the process of weighting the main evaluation criteria of bidders. Then another multi criteria decision making techniques are used for the process of bidders' evaluation, the techniques used are: -

- **TOPSIS** – Technique for Order of Preference by Similarity to Ideal Solution.
- **WSM** – Weighted Sum Model.
- **WPM** – Weighted Product Model.

The project is about **injection chemical skids.** The scope of work is fabrication, supply, instillation, commissioning and startup of a number of injection chemical skids.

6.1 SCOPE OF WORK

The scope of work includes the following activities:

- Fabrication of injection chemical skids
- Start Up and Commissioning for the supplied system
- Instillation of the supplied system
- Installation for the supplied materials or devices
- Interconnection with any other existing systems
- **Supply of**
    - ST.ST Materials (Piping, fitting, tubing…etc.).
    - Electrical materials (Cables, cables trays, glands. etc.).
    - Heat Trace System.

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- Tank.
- Double head chemical injection Pump.
- Immersion heater.
- Electric Mixer.
- Local Control Panel.
- Temperature Gauge Thermo well Pressure Gauge.

A compliance table including technical, contractual, quality and safety questions to be answered by bidders. This compliance table is scored by different departments involved in this project to make sure that all bidders are aware of the requirements. Based on this table, a score will be given to each bidder based on the provided answers, proofs, certificates or data sheets.

This contract is a lump sum contract based on a total lump sum price for the total project.

Decision Criteria

After the committee was established, meetings were held to determine the evaluation criteria. Based on previous experiences and scope of work the bidding committee decided on a two-level hierarchy the first level is the main objective of the committee which is the selection of the best technically and commercially accepted contractor the second level of hierarchy is the main evaluation criteria which are: -

1. Price.
2. Past Performance of bidders
3. Compliance with Technical questionnaire and Tender Requirements.
4. Delivery Duration.
5. Key Personnel CVS and qualifications.
6. After Sales Service.

NOTE

The Prices mentioned in this paper are not the real prices proposed by the bidders but multiplied by the same exact factor, this for secrecy declaration matters. So, the prices don't express the real project value.

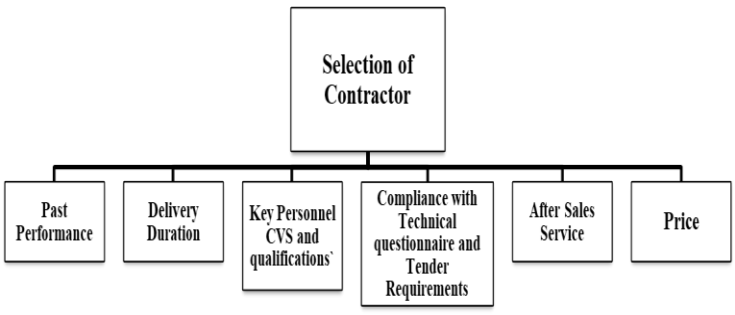

Figure 8. Criteria Hierarchy

6.2 The Process of Determining Weights of Criteria

The AHP method was implemented based on decision criteria displayed in Fig. 9. The committee members have implemented the AHP method. In AHP weightings, the relative importance of criteria in the same level is compared to obtain PWMs using the 9-value scale by Saaty. Seven members (three from the technical department, one from HSE and QA department, one from Finance and Planning department and two members from Contracts and Procurement department) in the commit-tee assessed the AHP weights. Each member completed one relative importance assessment table and, thus, generated only one PWM: one level-one PWM. In total, 7 (= 1×7) PWMs are acquired. This the total number of matrices required without checking the consistency. A check is made to check the consistency ratio is less than 0.10. if not a recalculation of the matrices is done.

1. Each committee member has to compare between the main evaluation criteria using the AHP method. This is done in one pair wise comparison matrix. Implementing this step, the main criteria weights will be assigned to the main evaluation criteria.
2. The final criteria scores were obtained by taking the average score per each criterion for each committee member. The final results can be found on the following tables.

Criteria- Members	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Overall, Criteria Weight
Price	0.404	0.376	0.406	0.430	0.279	0.426	0.478	**0.400**
Past Performance	0.135	0.071	0.100	0.038	0.103	0.067	0.043	**0.080**
Compliance with Technical	0.222	0.206	0.203	0.283	0.279	0.201	0.242	**0.234**
Delivery Duration	0.134	0.206	0.203	0.174	0.279	0.224	0.151	**0.196**
Key Personnel	0.052	0.071	0.038	0.037	0.030	0.047	0.043	**0.04558**
After Sales Service	0.052	0.071	0.049	0.037	0.030	0.036	0.043	**0.04551**

Table 11. Main Criteria Weights for CS-2.

6.3 Pair-Wise Comparison Matrices and Consistency Checks

All mathematical calculations have been done using software (OCTAVE GNU and EXCEL). The consistency of the matrices has been calculated for each pair-wise comparison matrix to mitigate the errors that may occur. The results are accepted as long as the consistency ratio is less than 0.10.

For sure and due to human error, the consistency ratio isn't less than 0.10 for all matrices and members had to reassign the values for the pairwise matrix to reach a value less than 0.10 to make sure that their choices are consistent and their judgement will be truly expressing their point of view. See the following table

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Assessment Cycle – Weighting Process	First	Second
No. of PWMS performed	7	1
No. and % of unacceptable PWMs	1 (14%)	0 (0%)

Table 12. Assessment Cycle for Weighting Process.

All members have participated in the process of assigning the weights for the main criteria, and their corresponding sub-criteria. We can say now that this process has a reasonable weight that can represent the personal opinion of each committee member and also reflect the experience and knowledge of each member during selecting the best bidder. Actually, this step has mitigated the drawbacks of the old selection methods by expressing the personal opinion without the influence of any other external factors that may influence the process. The process can be found in the following figure.

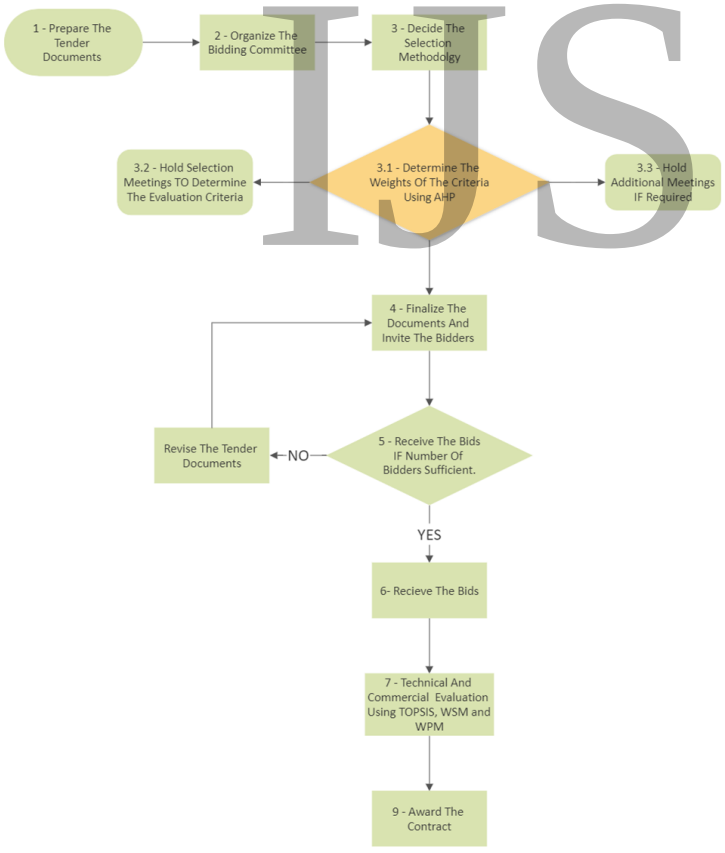

Figure 9. Weighing and Evaluation Process Using AHP, TOPSIS, WSM and WPM.

6.4 Analysis of The Weighting Process

From the previous results presented in previous tables for the process of assigning global and local weights of criteria and corresponding sub criteria. We can extract the following findings. **Figure 11** shows the results of the global criteria weights for all bidding committee members

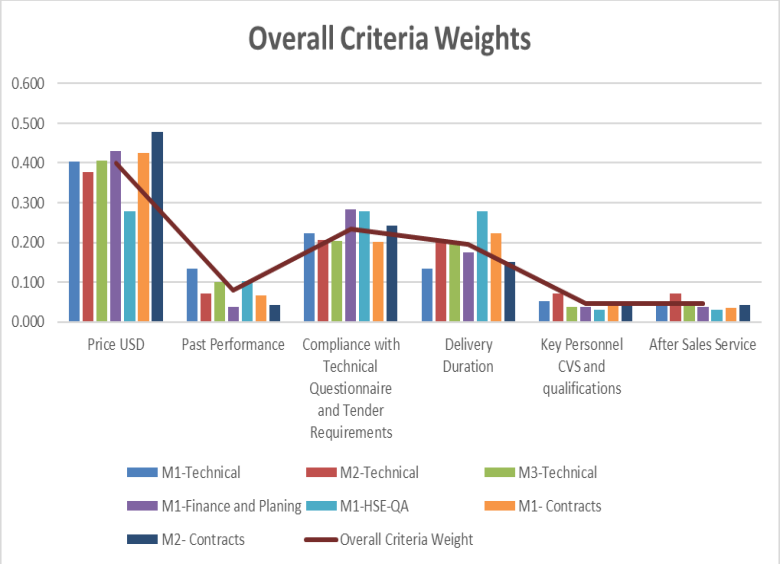

Figure.10 Overall Criteria Weights

- **Price** criterion got the highest weight of **0.400** as a main criterion which indicates the relative importance of that criterion and its corresponding sub criteria for that particular project when compared to other criteria. It can be seen that all members have put the highest priority weight to the Price as an evaluation criterion.
- The second priority overall weight of **0.234** is given to the **compliance with technical requirements**
- **Delivery Duration** criterion got **0.196** as an overall weight.
- **Past Performance** criteria got **0.08** as an overall weight.
- **Key Personnel qualifications and CVs** criterion got **0.045** as an overall weight.
- **After Sales Service** criterion got **.045** as an overall weight.

It can be seen that all the three members from the technical department have given the Price criterion the highest weight of an average weight of 0.395 which reflects their priorities for the project. Also, the delivery duration and technical compliance criteria have been given a reasonable average weight of 0.181 and 0.210 respectively. Past performance, key personnel qualifications and after sales service got an average weight of 0.102, 0.054 and 0.057 respectively for the three members.

All the three members from contract – finance departments have given the Price criterion the highest weight of an average weight of 0.444. Also, the delivery duration and technical compliance criteria have been given a reasonable average weight of 0.183 and 0.242 respectively. Past performance, key personnel qualifications and after sales service got an average weight of 0.049, 0.043 and 0.039 respectively, for the three members.

The member form HSE-QA-QC department has given the criteria of Price-Technical Compliance and Delivery duration same weight of 0.279 which indicated they are of equal importance while past per-

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formance has been given a weight of 0.103 and both key personnel qualifications and after sales service got 0.030.

It can be seen that nearly all members have chosen price as the most important criteria with an average overall weight of **0.400** representing 40% of the total criteria weight, meaning that this criterion will be crucial in the evacuation phase. Ranked the first as the most important criterion. The members agreed that compliance with technical questionnaire and tender requirements is of high importance and an average overall weight of 0.234 has been given to this criterion, representing 23.4% of the total evaluation criteria weight ranked the second most important criterion. The figure shows that the members agreed delivery duration is of importance and an average overall weight of 0.196 has been given to this criterion, representing 19.6% of the total evaluation criteria weight ranked the third most important criterion.

The figure also shows that the members nearly agrees that past performance, after sales service and key personnel qualifications criteria is less important when compared to other evaluation criteria thus, Past Performance criteria got 0.08 as an overall weight. Key Personnel qualifications and CVs criterion got 0.045 as an overall weight. After Sales Service criterion got .045 as an overall weight. All three criteria represent about 17% of the total evaluation criteria weight.

6.5 Bidders' Evaluation Process

Multi criteria decision making techniques are used for the process of bidders' evaluation, the techniques used are: -

•**TOPSIS** – Technique for Order of Preference by Similarity to Ideal Solution.

•**WSM** – Weighted Sum Model.

•**WPM** – Weighted Product Model.

Seven bidders have participated and proposed their technical and commercial bids to the bidding committee. Based on the technical proposals presented by the different bidders an evaluation process is executed to identify the highly qualified bidders and to choose the bidder that fulfills all the requirements of the evaluation criteria. It should be noted that all members have participated in the evaluation process of bidders.

Regarding the main criterion of **Compliance with Technical Questionnaire and Tender Requirements**, a technical questionnaire with a score of 100 Points covering all technical requirements, QHSE, QA – QC, and all related technical matters regarding the injection skids has been presented to the bidders with tender documents in order to be filled by the bidders and present-ed with the technical and commercial proposals.

A score out of 100 has been assigned for this technical questionnaire per each bidder based on the proposed answers, data sheets, any requirements (If any).

It should be noted that the price and delivery duration criteria are non-beneficial criteria, which means that the less values they are the better or more beneficial for the members, so that bidders with less delivery duration time and less prices are favorable to the committee members. All other criteria are beneficial criteria and the more values of them the better for the bidder.

The technical and commercial proposals of bidders included the following: -

1.Total lump sum Price for the project.

2.Bidder's prequalification and track record regarding the same scope of work.

3.The technical questionnaire with answers and proofs, requirements and data sheets.

4.The total delivery duration in for the chemical injection system (DDP-Incoterms 2010).

5.A brief of the after sales services and facilities (Maintenance workshops ...etc.).

So, during the process of evaluation of different bidders will be based on numerical values and estimations or based on the linguistic tongue when comparing between all of them.

- Prices (judgement according to comparing Numerical Values of Money of different bidders).
- Past experience and prequalification documents (judgement according to comparing the documents presented and give a verbal expression with linguistic tongue when comparing between bidders).
- The technical questionnaire scores (judgement according to Numerical scores of different bidders).
- Delivery (judgement according to comparing Numerical Values of duration of different bidders).
- A brief of the after sales services documents (judgement according to comparing the documents presented and give a verbal expression with linguistic tongue when comparing between bidders).

It should be noted in the evaluation process of bidders the proposed prices, technical scores and duration shall remain fixed as proposed by the bidder in the technical and commercial proposal

Likert Scale is used to convert the linguistic tongue expression into a numerical value in order to make all evaluation criteria comparable.

The 7-point Liker scale is used to have a wide variety of expressions for the committee members to express their feelings and expressions regarding bidders' submitted documents .

Very Poor	**1**
Poor	**2**
Fair	**3**
Good	**4**
Very Good	**5**
Excellent	**6**
Exceptional	**7**

Table 12. Likert 7-Point Scale

Criteria	Price	Past Performance	Compliance with Technical	Delivery + Instillation Duration	Key Personnel	After Sales Services
Bidder-1	NV*	Very Good	NV	NV	Excellent	Good
Bidder-2	NV	Excellent	NV	NV	Very Good	Very Good
Bidder-3	NV	Very Good	NV	NV	Good	Very Good
Bidder-4	NV	Good	NV	NV	Very Good	Good
Bidder-5	NV	Very Good	NV	NV	Good	Very Good
Bidder-6	NV	Very Good	NV	NV	Good	Good
Bidder-7	NV	Exceptional	NV	NV	Excellent	Excellent

*** NV - Numerical Value**

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Table 13- shows the evaluation form before using Likert 7 Point scale. (Example)

Criteria	Price	Past Performance	Compliance with Technical	Delivery + Instillation Duration	Key Personnel	After Sales Services
Bidder-1	NV*	Very Good	NV	NV	6	4
Bidder-2	NV	Excellent	NV	NV	5	5
Bidder-3	NV	Very Good	NV	NV	4	5
Bidder-4	NV	Good	NV	NV	5	4
Bidder-5	NV	Very Good	NV	NV	4	5
Bidder-6	NV	Very Good	NV	NV	4	4
Bidder-7	NV	Exceptional	NV	NV	6	6

Table 14- shows the evaluation form after using Likert 7 Point scale. (Example)

6.6 Description of The Evaluation Process

1.Each committee member has to compare between the bidders based on the suggested evaluation criteria.

2.The price values, technical compliance scores and delivery duration in Months are fixed numerical values based on the proposals presented by the different bidders. The scores of the technical compliance are given and corrected by all committee members and corresponding taskforce.

3.Each committee member shall express his/her opinion and express feelings regarding the different proposed documents, evidences, data sheets or any related document proposed by the different 7 bidders. For the criteria of (Past Experience, Key Personnel CVs and qualifications and After Sales Services). This is done using the expressions given by Liker 7-point scale. It should be noted that the 7-point scale is used not the 3 nor 5-point scale to give a wider range of expressions so that the committee members have the ability to express themselves.

4.Converting the linguistic tongue expressions into a numerical value with the help of Likert 7- Point scale. Each member after completing the evaluation steps stated in the previous steps will have a table like shown in previous tables (See previous example shown in tables).

5.After implementing the above steps, we are able use the MCDM different techniques like (TOPSIS-WPM-WSM) for evaluation of bidders for each member, in order to get a performance value for each bidder per each committee member, so that each member after implementing the MCDM technique will have 7 different performance scores for the 7 bidders, then a rank from the higher to the lower so that the bidder with highest performance score will have the rank first -1 and the one with lowest performance score will have the last rank rank-7.

6.After implementation of the previous steps for each committee member, we will have 7 different ranks for the 7 committee members. (Seven Different Ranks for the 7 bidders for each committee member).

7.Taking the average overall performance value per each bidder for the seven members then comparing the final overall average performance value for each MCDM methods, the bidder with the highest final overall performance value (first rank) shall be winner.

The following tables shows the bidders qualifications and rank based on the average input of the committee members regarding their submitted proposals (The exact input per each committee member is used in our mathematical calculations) just to show the reader the general impression

NOTE The Prices mentioned in this paper are not the real prices proposed by the bidders but multiplied by the same exact factor, this for secrecy declaration matters. So, the prices don't express the real project value.

Bidders Ranks Per Criteria	Price	Rank
Bidder-1	2,714,003.00	5
Bidder-2	2,890,500.00	6
Bidder-3	2,620,680.00	4
Bidder-4	2,350,000.00	3
Bidder-5	2,050,000.00	1
Bidder-6	2,230,000.00	2
Bidder-7	2,945,360.00	7

Table 15 Prices Rank 40%.

The Prices mentioned in this paper are not the real prices proposed by the bidders but multiplied by the same exact factor, this for secrecy declaration matters. So, the prices don't express the real project value.

Price is a Non- Beneficial Criteria, so bidders with lower prices are favorable. The best Prices are proposed by Bidder-5. Bidder-5 is the lowest price. Bidder-6 is higher price than Bidder-5 by nearly 9%. Bidder-7 ranked 7th in the price criteria with a higher price by 44% than the lowest price of Bidder-5.

Bidders Ranks Per Criteria	Technical	Criteria Rank
Bidder-1	**88**	**3**
Bidder-2	**92**	**1**
Bidder-3	**83**	**6**
Bidder-4	**88**	**3**
Bidder-5	**79**	**7**
Bidder-6	**85**	**5**
Bidder-7	**92**	**1**

Table 16 Technical Rank 23.4%

As shown from the previous table that Biddrr-7 and Bidder-2 have got the highest technical scores of 92 out of 100, based on the compliance tables, technical documents presented with their proposals based on the predetermined scored technical compliance tables. Bidder-6 has got 85 out of 100 representing 8% less than the score assigned to Bidder-7 and Bidder-2 and ranked the fifth in the technical criteria. Bidder-5 Scored 79 and ranked 7th representing 15% less than Bidders-7-2.

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Bidders Ranks Per Criteria	Delivery Duration In Months	Criteria Rank
Bidder-1	8	2
Bidder-2	8	2
Bidder-3	7	1
Bidder-4	9	6
Bidder-5	10	7
Bidder-6	8	2
Bidder-7	8	2

Table 17 Delivery Rank 19.6%

Delivery duration is a Non- Beneficial Criteria, so bidders with lower duration are favorable. Bidder-3 is the 1st rank regarding this criterion with 7 months duration for delivery. Most of the Bidders proposed 8 months as a duration. Bidder-5 proposed 10 Months as a duration and ranked 7th in this criterion.

Members scores Likert Scale	M	M	M	M	M	M	M	Average Score	LT	Rank
Past Performance = 8% weight										
Bidder-1	7	5	5	4	5	5	5	5.1	V.Good - Excellent	2
Bidder-2	7	5	5	4	4	5	6	5.1	V.Good - Excellent	2
Bidder-3	5	5	4	4	5	5	5	4.71	Good - V. Good	4
Bidder-4	5	4	4	4	5	4	4	4.2	Good - V. Good	5
Bidder-5	4	4	3	3	4	4	5	3.86	Fair-Good	6
Bidder-6	4	3	3	3	3	5	5	3.71	Fair-Good	7
Bidder-7	7	5	5	5	6	7	7	6.00	Excellent	1
Key Personnel CVs and qualifications = 4.558 % weight										
Bidder-1	4	5	4	4	5	6	6	4.86	Good-V. Good	2
Bidder-2	4	5	4	4	3	5	5	4.2	Good-V. Good	3
Bidder-3	4	5	4	4	4	4	4	4.1	Good-V. Good	4
Bidder-4	4	4	3	4	3	4	5	3.86	Fair-Good	5
Bidder-5	3	3	4	3	4	4	4	3.57	Fair-Good	6
Bidder-6	4	3	4	2	3	4	4	3.43	Fair-Good	7
Bidder-7	5	6	5	4	7	6	6	5.57	V.Good-Excellent	1
After Sales Service = 4.551% weight										
Bidder-1	5	4	4	4	3	4	4	4.00	Good	4
Bidder-2	4	2	4	5	4	5	5	4.1	Good-V. Good	2
Bidder-3	4	3	4	5	4	4	5	4.1	Good-V. Good	2
Bidder-4	4	4	3	4	4	4	4	3.86	Fair-Good	5
Bidder-5	3	2	3	3	4	5	5	3.57	Fair-Good	6
Bidder-6	4	3	3	3	3	4	4	3.43	Fair-Good	7
Bidder-7	5	4	5	5	7	6	6	5.43	V.Good	1

Table 18 Average linguistic Scores Assigned to Criteria for General Impression about the bidders' proposals

The previous table shows the input of the committee members using Likert scale to convert their linguistic expressions, regarding different criteria proposed documents by bidders, into numbers and also shows the average score of the members inputs regarding Past performance, After Sales service and Key personnel CVs and qualifications. Which will give a general expression about the average feedback of the members for the different bidders regarding those particular three criteria. It can be seen that most of the bidders are within the same range except for bidder-7 which is considered a little bit more qualified regarding those particular criteria of (Past performance, key personnel and after sales services.)

Weight of Criteria	40 %	23.4%	19.6%	8%	4.558%	4.551%
Bidders Ranks per Criteria	Price	Technical Compliance	Delivery Duration	Past Performance	Key Personnel	After Sales Service
Bidder-1	5	3	2	2	2	4
Bidder-2	6	1	2	2	3	2
Bidder-3	4	6	1	4	4	2
Bidder-4	3	3	6	5	5	5
Bidder-5	1	7	7	6	6	6
Bidder-6	2	5	2	7	7	7
Bidder-7	7	1	2	1	1	1

Table 19 Shows the general rank of bidders based on their scores per each evaluation criterion

It can be seen that Bidder-7 is the highest prices but also the highest ranks regarding other evaluation criteria, while Bidde-5, Bidder-6 and Bidder-4 are the lowest prices (40% of total weight) but are nearly the same in the evaluation (a little bit less) when compared to other bidders with much higher prices when it comes to past performance, key personnel and after sales services (17.1% of total weight). Bidder-4 and Bidder-5 are the last rank regarding the delivery duration criterion (19.2% of weight), other bidders are the same rank except Bidder-3 is the first rank regarding delivery duration. Bidder-5 is the last rank in technical compliance criteria.

6.7 Evaluation Process for The Bidders Using TOPSIS Method

TOPSIS has been commonly used for MCDM and based on comparing all alternatives and deciding the best one which will have the shortest distance (Euclidean distance from the ideal solution). Vector normalization is done to compare between alternatives then we get weighted normalized decision matrix with the help of AHP. Eventually we calculate the ideal best and ideal worst alternative and Euclidean distance from ideal best and worst for each alternative after that we will be able to get the performance score for each alternative (Highest score is the best alter-native). Now having the pair wise comparison matrix ready with numerical values per each criterion for the seven bidders. We may use the different Multi Criteria Decision Making Techniques. Starting with TOPSIS, The TOPSIS method was first introduced by Yoon and Hwang and ap-praised by surveyors, and various operators. TOPSIS is a decision-making technique. is a goal-based approach to find the closest alternative to the ideal solution. This method evaluates options based on the ideal solution Similarity. An option is graded higher if it resembles or similar to the ideal solution. The ideal solution is in every way the best that doesn't really exist, and TOPSIS technique tries to find the alternative that comes close to the ideal solution. Basically, for measuring similarity of an alternative (or option) to ideal level and non-ideal, we consider distance of that option from ideal and non-ideal solution.

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Bidders Performance Scores TOPSIS	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Average Performance Score	Final Rank
Bidder-1	0.428	0.430	0.413	0.399	0.390	0.378	0.378	0.4022	**5**
Bidder-2	0.356	0.345	0.349	0.344	0.298	0.313	0.334	0.3343	**7**
Bidder-3	0.480	0.509	0.488	0.503	0.478	0.468	0.474	0.4856	**4**
Bidder-4	0.576	0.591	0.566	0.595	0.547	0.534	0.544	0.5647	**3**
Bidder-5	0.597	0.609	0.606	0.604	0.594	0.598	0.619	0.6038	**2**
Bidder-6	0.670	0.659	0.665	0.647	0.580	0.678	0.682	0.6544	**1**
Bidder-7	0.356	0.360	0.352	0.357	0.409	0.361	0.356	0.3644	**6**

Table 20 Evaluation Process for The Bidders (Using TOPSIS Method)

Previous Table shows the different ranks for the seven bidders per each committee member based on the performance scores presented by applying TOPSIS method to the evaluation pair-wise matrices.

The table shows the average overall performance scores of bidders then a descending rank so that the bidder with highest final performance score is ranked first, which can be seen from the above table that Bidder-6 is the winner with the first rank among other bidders. Note:- Descending rank, the largest value is ranked as 1. Ascending rank, the largest value is ranked as 1.

Applying TOPSIS method, Bidders 6 ranked the first among all other bidders although this Bid-der is not the lowest price nor the most qualified regarding experience and qualifications.

Bidder-2 which are considered one of the highest qualified bidders regarding the three criteria of past performance, after sales service and key personnel (17% of total criteria weight). Bidder-2 is ranked 7th. It should be noted that Bidder-2 is the second highest prices among other bidders. With the fact that price is considered the most important criterion of 40% weight among other criteria, we can say Bidder-2 is highly qualified but didn't achieve good scores for the important criteria of high considerable weights like Price, as Bidder-2 presented a very high prices of nearly 42% more than the least price presented by Bidder-5, and 30% pf the prices presented by the winner Bidder-6. TOPSIS have considered the assigned weights by giving high priority to the criteria with high weight and a less priority for criteria with less weights, and chosen the ideal alternative or similar to the ideal based on the weights assigned by the committee members. Bidders-6 is not the lowest price and also not the most qualified but, Bidder-6 got a good score when it comes to the criteria that really have an influence like Price (40% weight), Technical Compliance (23.4% weight) and Delivery duration (19.6% weight), and achieved all the requirements by all commit-tee members and considered to be GOOD regarding other three criteria of Past experience, Key personnel and After sales service (total weight of 17.1%).

6.8 Evaluation Process for the Bidders using WSM Method

WSM Weighted sum model is another model for selection after assigning weights of each criterion and doing vector normalization we multiply the weights of each criterion by the normalized vector getting weighted normalized decision matrix then based on summation of each criterion for one alternative we can get our preference score the choosing the highest to be our best selection.
the weighted sum model (WSM) also called weighted linear combination (WLC) or simple additive weighting (SAW), is one of the simplest techniques in MCDM techniques and is considered to be the earliest technique for decision making problems that enable users to select between different alternatives and is suitable for simple problems and criteria of a well-defined numerical values. WSM allows the comparison of the alternatives by assigning scores, and then using these scores, standard values are generated for the alternatives under consideration. So, overall, the results are in the form of good, better and best. The criteria are given weights depending on the severity of each; sum of all these weights must be 1. Each alternative is assessed with respect to every attribute. weights calculated earlier by the seven committee members using AHP (Analytical Hierarchy Process).

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Bidders Performance Scores WSM	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Overall Average Performance Score	Final Rank
Bidder-1	0.858	0.860	0.849	0.843	0.815	0.830	0.830	0.84067	6
Bidder-2	0.841	0.829	0.841	0.843	0.787	0.821	0.833	0.82794	7
Bidder-3	0.849	0.871	0.856	0.874	0.838	0.837	0.845	0.85280	3
Bidder-4	0.854	0.864	0.843	0.870	0.836	0.831	0.838	0.84820	4
Bidder-5	0.838	0.847	0.849	0.847	0.843	0.851	0.863	0.84816	5
Bidder-6	0.873	0.859	0.866	0.853	0.834	0.872	0.872	0.86143	1
Bidder-7	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.85397	2

Table 21. Evaluation Process for The Bidders (Using WSM Technique)

Previous Table shows the different ranks for the seven bidders per each committee member based on the performance scores presented by applying WSM method to the evaluation matrices. The table shows the average overall performance scores of bidders then a descending rank so that the bidder with highest final performance score is ranked first, which can be seen from the above table that Bidder-6 is the winner with the first rank among other bidders.

Applying WSM method, Bidders 6 ranked the first (same as TOPSIS). While Bidders 4-5 got a middle rank of 4th and 5th respectively. Bidder-2 got the last rank (the same as applying TOPSIS). So, it can be concluded that using WSM. Bidder-6 got the first rank achieving a reasonable price, technical score and good delivery duration when comparing to other bidders, while Bidder-2 achieved the last rank as it represents a high price and nearly the same (little bit higher) qualifications, after sales services of other bidders but less than Bidder-7. Bidder-7 is ranked second, despite being the highest price among other bidders but also the most qualified when compared to other bidders regarding the past performance, key personnel and after sales services (17.1% of total weight). Bidder-3 ranked the third, with a reasonable price (third rank) of about 14% more than the least price and 5% more price than Bidder-6, and a reasonable qualification and the least delivery du-ration of 7 months.

6.9 Evaluation Process for The Bidders Using WPM Method

WPM Weighted Product model is another model for selection after assigning weights of each criterion and doing vector normalization. we get the weights of each criterion to be the power of normalized vector getting weighted normalized decision matrix then based on multiplication -product of each criterion for one alternative we can get our preference score then choosing the highest to be our best selection.

Weighted product model (WPM) is the extension of the weighted sum model (WSM) with differences. The main difference is that instead of addition in the main mathematical operation, there is multiplication. The same steps of WSM are applied regarding the normalized decision matrix, the big differences are: -

- When, assigning the criteria weights to the develop the weighted normalized decision matrix, in WSM we multiply the criteria weight by the normalized element to get the weighted normalized value vij, while in WPM the normalized value vij is calculated by raising the normalized element to the power of the corresponding criteria weight. The steps are shown below.
- To get the performance score of alternatives in WSM, we add the weighted normalized values vij per each ith alternative (bidder), while in WPM we multiply instead of addition.

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Bidders Performance Scores WPM	M1T	M2T	M3T	M1FP	M1HQ	M1CP	M2CP	Overall Average Performance Score	Final Rank
Bidder-1	0.8531	0.8547	0.8445	0.8381	0.8048	0.8237	0.8237	0.8346	5
Bidder-2	0.8321	0.8160	0.8321	0.8342	0.7711	0.8131	0.8250	0.8176	7
Bidder-3	0.8442	0.8662	0.8519	0.8694	0.8288	0.8303	0.8388	0.8471	2
Bidder-4	0.8510	0.8603	0.8365	0.8675	0.8246	0.8223	0.8307	0.8419	4
Bidder-5	0.8216	0.8300	0.8357	0.8332	0.8280	0.8380	0.8530	0.8342	6
Bidder-6	0.8666	0.8491	0.8587	0.8405	0.8101	0.8676	0.8676	0.8515	1
Bidder-7	0.8428	0.8428	0.8428	0.8428	0.8428	0.8428	0.8428	0.8428	3

Table 22 Evaluation Process for the bidders (Using WPM)

Table shows the different ranks for the seven bidders per each committee member based on the performance scores presented by applying WPM method to the evaluation matrices. The table shows the average overall performance scores of bidders then a descending rank so that the bidder with highest final performance score is ranked first, which can be seen from the above table that Bidder-6 is the winner with the first rank among other bidders.

Applying WPM method, Bidders 6 ranked the first (same as TOPSIS and WSM). Bidder-2 got the last rank (the same as applying TOPSIS and WSM). So, it can be concluded that using WPM. Bidder-6 got the first rank achieving a reasonable price, technical score and good delivery duration when comparing to other bidders, while Bidder-2 achieved the last rank as it represents a high price and nearly the same qualifications of other bidders. Bidder-3 ranked the second, with a price (fourth rank) of about 27% more than the least price and 17% more price than Bidder-6, and a reasonable qualification and the least delivery duration of 7 months.

Bidders' Ranks MCDM Techniques	TOPSIS	WSM	WPM
Bidder-1	5	6	5
Bidder-2	7	7	7
Bidder-3	4	3	2
Bidder-4	3	4	4
Bidder-5	2	5	6
Bidder-6	1	1	1
Bidder-7	6	2	3

Table 23 Different Rank of Bidders Using TOPSIS, WSM and WPM.

6.10 Discussion and Analysis

Rank	TOPSIS	WSM	WPM
1	✓	✓	✓
2	x	x	x
3	x	x	x
4	x	✓	✓
5	✓	x	✓
6	x	x	x
7	✓	✓	✓
✓ - Same Bidder		**X – Different Bidder**	

Table 24. Rank Similarity Using TOPSIS, WSM and WPM

All the three methods have the same rank of bidders for the first rank (Bidder-6) and the seventh rank (Bidder-2). Representing 29% match for the three MCDM methods. TOPSIS and WPM have the same ranks, three times for first (Bidder-6), fifth (Bidder-1) and seventh (Bidder-2). Representing 43% match for the two MCDM methods.

TOPSIS and WSM have the same ranks, two times for first (Bidder-6) and seventh (Bid-der-2). Representing 29% match for the two MCDM methods. WPM and WSM have the same ranks, three times for the first rank (Bidder-6), fourth rank (Bidder-4) and the seventh rank (Bidder-2). Representing 43% match for the two MCDM methods.

Match %	TOPSIS	WSM	WPM
TOPSIS	**100%**	**29%**	**43%**
WSM	**29%**	**100%**	**43%**
WPM	**43%**	**43%**	**100%**
Overall Match for the three methods			**29%**

Table 25. Match Percentage

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So, it can be concluded from the results shown in the above tables that, TOPSIS method shows a match regarding the bidder's results with WPM of 43% and a less match of 29% with WSM. WSM and WPM shows a match of 43%. So, WPM matches the same of 43% with other two MCDM techniques of TOPSIS and WSM. Although the three MCDM techniques showed the same results for the first and last rank of bidders, the overall match of results is 29% which indicates that the results are different for other remaining ranking positions. But eventually all of the three techniques confirm that Bidder-6 is the winner achieving a combination of reasonable price, sufficient technical capabilities and past performance with reasonable delivery duration and fair after sales services. Despite the fact that this bidder is not the least price and also not the highest qualified regarding experience matters.

From the above analysis we can conclude the following, all the three criteria of TOPSIS, WSM and WPM have scored Bidder-6 as the highest performance score based on the evaluation of the committee members to the proposed technical and commercial offers presented by this bidder and also all of the three MCDM techniques have chosen Bidder-2 with the least performance score among other Bidders.

The price criterion was so crucial in the evaluation process as it represented 40% of the total weight of the proposed criteria by the bidding committee, although Bidder-6 was not the least prices but the second least prices, still ranked first using all of the three techniques.

We may say that TOPSIS method is more sensitive regarding the criteria weights proposed by the bidding committee and this can be seen from rank, the lowest prices (criteria = 40% of the total weight) in the three top ranks, which is very reasonable and was found satisfying by the bidding committee members as they found that this method really expressed the ideal bidder to execute the contract.

From the above we can see that despite Bidder-7 is the highest Price by nearly 44% of the lowest price and price represents 40% of the total weight but still achieves an advance position using WSM and WPM, on the other hand Bidder-7 ranked a late rank of 6th using TOPSIS. While Bidder-5 the lowest price achieves an advance rank of 2nd using TOPSIS and late ranks using WSM and WPM.

All the three methods have the same rank of bidders for the first rank (Bidder-6) and the seventh rank (Bidder-2). Representing 29% match for the three MCDM methods.

TOPSIS and WPM have the same ranks, three times for first (Bidder-6), fifth (Bidder-1) and seventh (Bidder-2). Representing 43% match for the two MCDM methods.

TOPSIS and WSM have the same ranks, two times for first (Bidder-6) and seventh (Bidder-2). Representing 29% match for the two MCDM methods.

WPM and WSM have the same ranks, three times for the first rank (Bidder-6), fourth rank (Bidder-4) and the seventh rank (Bidder-2). Representing 43% match for the two MCDM methods.

So, it can be concluded from the results shown in the above tables that

- TOPSIS method shows a match regarding the bidder's results with WPM of 43% and a less match of 29% with WSM.
- WSM and WPM shows a match of 43%. So, WPM matches the same of 43% with other two MCDM techniques of TOPSIS and WSM.
- Although the three MCDM techniques showed the same results for the first and last rank of bidders, the overall match of results is 29% which indicates that the results are different for other remaining ranking positions. But eventually all of the three techniques confirm that Bidder-6 is the winner achieving a combination of reasonable price, sufficient technical capabilities and past performance with reasonable delivery duration and fair after sales services. Despite the fact that this bidder is not the least price and also not the highest qualified regarding experience matters.

It can be seen that Bidder-5 in TOPSIS ranked the second although Bidder-5 is the least prices, this might be due the proposed delivery duration of the bidder of 10 months while Bidder-6 is 8 months. This criterion represented 19.6% of the total weight. And also, Bidder-5 was nearly the same regarding other criteria of past performance, key personnel and after sales services.

The results might be better if in future tried to score the bidders aside from the linguistic expression, like what have been done with the pre scored technical compliance tables or at least try to minimized the use of non-numerical criteria in order to avoid conversions.

Using the existing evaluation of criteria, and since all bidders are considered to be technically accepted, Bidder-5 with the least proposed prices would have been awarded the contract, but using the MCDM techniques Bidders-6, with proposed prices more than Bidder-5 is considered the winner as this bidder accomplished all the required criteria with reasonable technical and commercial proposals.

7 Conclusion

This work tests the AHP, TOPSIS, WSM and WPM application suitability for assessment of the contractor selection process for two real case studies of two petroleum projects in Egypt. To overcome the drawbacks of the old methods which didn't capture all the preference of the members of the selection committee. The AHP showed a great positive impact during the process of assigning weights to the proposed main and sub evaluation criteria, as it captured all the committee members preferences, background and knowledge when assigning the relative criteria weights, which can be seen in the two case studies, not only that but it also provided a tool to express the linguistic expressions of the committee members which was not possible with the old methods. The MCDM techniques proposed the best contractor for the project based on the entered data by the committee members and the proposed data by the different bidders.

The results showed differences in weights during the process of assigning the weights, which confirms that AHP has captured the different background and knowledge of the committee members, the results also showed that, human mind tends to exaggerate the unknown, as members with no related experience in a specific field assigned a higher relative weight to it.

Awarding the contract to the bidder with lowest price is not necessarily the outcome the commit-tee seeks as other bidders with higher proposed prices (Still reasonable prices) and are technically more qualified and will provide the required job better than the bidder with the lowest prices. So those methods provided a way to express the relative importance of the evaluation criteria which can be greatly seen in the second case study, as the winner is not the best price and not the most technically qualified but a combination of good prices and sufficient technical quality.

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The project scale and scope play a pivotal role when assigning the weights of the evaluation criteria and their corresponding sub-criteria. As can be seen in case study one the technical criteria played a pivotal role in deciding the most technical qualified bidders as this type of project re-quired a high technical equipment.

Two of the greatest advantages this study showed are, firstly the flexibility of these techniques to accommodate the different criteria, opinions, weights to propose the bidder with perfect com-bination, which can be seen in both studies. Secondly the systematic mathematical models which can be, with practice, easily understood and implemented by anyone. The combination of (subjective - objective) and (qualitative – quantitative) data is possible while using these techniques.

7.1 Recommendations for future studies

The use of further initiatives to share practical experience should be the main emphasis of future work. The case studies indicated that committee members typically overlook the importance of the technical criteria in their own specialty, but they overemphasize those with which they are unfamiliar. As a result, we suggest using a strategy that includes as many domain experts as possible with different backgrounds in the selection committee. The long time required to implement the AHP limits its use. Thus, any methodology that shortens the AHP implementation time will be of a great value. Instead of using Likert Scale to convert the linguistic expressions into numerical values, fuzzy methods like FAHP and FTOPSIS can be investigated to give a wider range to express the linguistic term of the committee members. The legalization of those methods to match the Egyptian laws should be addressed for further implantations of those techniques.

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