# Integrated Model for Selecting the Best-Value Contractor in Construction Projects in Egypt

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**Abstract**— Selecting the best-value contractor is not always an easy decision to make. Clients tend to choose the lowest bid price which doesn't always guarantee the accomplishment of the work according to the terms and conditions of the contract, so that the technical proposal of the contractor has to be considered to accurately choose the best one. Contractors who submit a high bid prices shouldn't be disqualified as they might have a high technical ability which allows them to award the contract, so that this research tried to convert the contractor technical score into price and then subtract this price from the submitted bid price to obtain a final bid price which represents a combination of the technical and financial proposal of the contractor.
For this research, the analytical hierarchy process (AHP) was used as a decision support tool for contractor selection as it shows a great accuracy while comparing a list of alternatives.To establish the structure of the hierarchy, the technical criteria that are used to evaluate the contractors were divided into six main groups as follows: financial soundness, management capabilities, experience, resources, health & safety and reputation, and each main group contains its sub-criteria. The geometric mean was used to aggregate the participant's opinion.
The expert's opinion and points of views were obtained through a questionnaire. The questionnaire was sent to 145 participants and had a high rate of responses as 105 were the total number of the completed questionnaires. 41% of the participants were project managers, 33.3% were consultants, 15.2% were tender evaluators and 10.5% were company executives. 68.6% of the respondents work for private sectors, while 31.4% works for public sectors. 41% of the respondent had experience from 10 to 20 years.
The results showed that for the project scale ≤ 5M, financial soundness has a great effect on the technical success of the contractor as it weighs 47% of the total technical evaluation. "Past failure to perform the contract", "Availability of skilled supervisors", "Management Knowledge", "Safety management accountability", "Experience of the technical personnel" and "Liquidity" were found to be the most important technical sub-criteria for contractor selection.
A contractor selection software has been designed to make the process of evaluating the contractors' technical and financial proposal easier and to save time to the person who's responsible for awarding the contract. To completely understand how does the evaluation work, a hypothetical case study was applied to four bidders who compete for awarding the contract of constructing a residential compound. The results showed that the contractor who submitted the lowest bid price was ranked 2nd.

**Index Terms**— Analytical hierarchy process, Bid evaluation, Contractor selection methodology, Contractors' evaluation criteria, Contractor selection software



## 1 Introduction

Alternatives forms of project delivery have been increased in the last two decades. However, the performance of the construction project doesn't run as expected as many projects have ended up with delay, cost over-run and low work standards, where owners tend to award the contract to the contractor who submits the lowest bid price which doesn't always guarantee the accomplishment of the work according to the plans. Hardy (1978) argued that the low bid doesn't always propose the best value of money to the client, as the bid price effectively represents a cumulative series of payment over time. So that for the successful completion of a project, a full and precise assessment of contractors' technical ability is required. Selecting an appropriate contractor to award the contract is one of the most important tasks that should be accurately done to ensure the success of the project.

### 1.1 Research Problem

In accordance to law (89/1998), the system of bid evaluation in the public sectors in Egypt is dominated by the principle of accepting the lowest bid price from the contractors who have a technical specification that meets the terms and condition of the tender while maintaining the concept of equal opportunities and equality between the bidders while evaluating the technical proposal of the contractors. However, contractors who submit a high bid prices shouldn't be disqualified as they might have a high technical ability which allows them to award the contract so that the methodology and the procedures for evaluating the bids should consider how high the technical proposal of the contractor is.
Law (89/1998) also stated that the technical proposal of the contractor can be evaluated using the "Point system" if it was involved in the condition of the tender, where the contractor's bid price is divided by his technical score and then prioritize the contractors according to the calculated ratio by the evaluation committee. However, the selection process may be based on the lowest bid price from the contractors who get or exceed the minimum technical required score that the competent authority has identified for the project.
law (182/2018) as a new law for tendering was introduced in Egypt to replace the previous law, but the methodology and the procedures for evaluating the technical proposal of the contractor haven't been changed.

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Many methodologies for evaluating the bids have been in practice, but is there a difference between choosing the contractor based on the lowest bid price only and choosing the contractor based on the strength of his technical proposal and his reasonable bid price which is not necessary to be the lowest?

### 1.2 Research Objectives

I. To assign the contractor who has the best technical abilities.
II. To identify the degree of importance of each technical criterion that are used to evaluate the contractors.
III. To develop a decision-support model to easily choose the best contractor who has a combination of a perfect technical and financial ability.

## 2 Literature Review

### 2.1 Analytical Hierarchy Process

The Analytical Hierarchy Process is a decision-support tool which was developed by Dr. Thomas Saaty in the 1980s [2], AHP is considered an efficient and flexible multi-criteria decision-making process that assists managers and professionals to assign priorities for each criterion and make the best decision. The AHP is not designed to substitute any other decision tool, it organizes the thoughts and ideas and makes them clear to others. The real strength of AHP lies in treating the decision as a system, which is difficult for many decision-makers to do due to the number of factors involved in a complex decision. The AHP model breaks down the complex structures to a hierarchical sequence to assign the relative importance of each alternative through pair-wise comparisons. The AHP measures the quality of the input data which is considered a unique feature, it also measures the inconsistency, which gives the decision-makers the chance to assign judgments that need reassessment.

#### 2.1.1 Application of Analytical Hierarchy Process

The preferences of the graduate students were examined using the Analytical Hierarchy Process. Four learning activities were found to be employed in the adult educational settings, they were: individual projects, group-based projects, in class discussion and lectures. A questionnaire was distributed among 134 students that have different age range and was designed to assign the strength rate of each alternative. the results showed that the adult graduate prefer to learn by discussion and reflection to lecture and prefer individual projects to group projects [3].

The health care service performance was measured using the Analytical Hierarchy Process. Factors affecting the performance of the healthcare process in hospitals were gathered by conducting brainstorming sessions and distributing a questionnaire survey among the clinicians and managers in both India and Barbados. Three main criteria that are used as an indicator for the performance of healthcare in hospitals were identified: patient care sector, establishment sector, administrative sectors and patient care sector.

Patient care sector's factors were: accident & emergency, operating rooms, intensive care units, outpatient clinics, general awards and physical therapy unit. Establishment sector's factors were: pharmacy management, laboratory sciences, patient nutrition, communication systems and library/academic activities. While, administrative sector's factors were: overall supply-chain management, human relations and personal management of staff, financial management, clinical engineering and medical records management. The results showed that the "patient care" ranked first followed by "establishment sector". The study concluded that the Analytical Hierarchy Process is a powerful tool for the measurement of the healthcare performance [4].

### 2.2 Prequalification

For the project improvement and a precise decision of choosing a contractor, a prequalification stage is required as it involves the screening of the contractors by the person who's responsible for awarding the contract based on a set of criteria and requirements.

The aim of the prequalification stage is to identify the contractors who have the ability to perform the work satisfactorily [6] and also to ensure a competitive and better evaluation of the bid submitted by the contractors that have the same classification [1].

### 2.3 Evaluation of Bid

Bid evaluation is the process that comes after the tender submission. It involves the opening and the evaluation of the bids to identify the perfect contractor who has the ability to accomplish the work satisfactorily. The concept of the competitive bidding is deeply rooted in the American tradition, where New York state has used this concept since 1847 [7]. The purpose of this concept is to choose the lowest bidder.

The system of choosing the lowest bidder was established in the U.K in the early 19th century [8]. After recognizing the inadequacy of the concept of the lowest bidder, many countries have done some modification to that concept. Thus, there are two types of selecting the contractor in practice – the lowest bid system and the non-lowest bid system.

#### 2.3.1 Lowest Bid Price

The original purpose of the competitive bidding is to ensure that the competition among all the bidders is free and fair [17]. Bid evaluation in the United Kingdom for the public sector is subjected to the concept of choosing the lowest price bidder [1]. The same situation is in Canada and USA where the contracts are awarded to the bidder who submits the lowest bid price but the bidder is asked to submit a bid bond that has an amount of 10% of the total bid price [16].

using the lowest bid system is not always effieient where the system doesn't always lead to low out-turn prices and the bid price might be unrealistic [1].

It was argued that the lowest bid price doesn't always lead to the best value of money where the bid price represents a cumulative series of payment over time [9].

### 2.3.1 Non-Lowest Bid Price

Some modifications have done to the concept of choosing the lowest bidder by many countries and developed new approaches to evaluate the bids [10.11].

In Denmark, the two lowest and the two highest bidders are disqualified and the closest to the average of the remaining are selected [11]. A similar approach has been used in Italy, Portugal and South Korea, but those countries exclude only the highest and the lowest bidder [11]. In Saudi Arabia, the contractor who submits the lowest bid price is selected but his bid price shouldn't be lower than the owner estimated cost by 30%, so his bid price must not be less than 70% of the estimated cost [12]. France excludes the abnormal low bids that could cause problems during the implementation process.

### 2.4 Contractor Selection

A new time & cost approach was developed to determine the bidder who deserves to be awarded a highway construction contract. using this method, a road user cost is applied to the contract time proposed by each contractor. The criteria considered were the contract time and the bid price. the road user cost was applied to the contract time by converting the contract time into price to the client [11].

preparing a suitable bid list between the engineer and the client was suggested. The list included contractors who were qualified in the prequalification stage. The technical ability of the contractor has to satisfy the engineer and the client at the same time. contractors should have a financial strength to be able to finance the project, experience of the similar projects and ability to handle the current project, plant capacity, human resources, testing and quality control capability [14].

The issues of contractor selection in Lithuanian companies was analyzed. The required data was obtained through a questionnaire survey. Four evaluation criteria were considered in the study: the bid price, legal requirements, financial criteria and technical and management criteria. The participants were asked to choose one degree of importance for each criterion. The results showed that the bid price is the most important factor that has a significant effect on the contractor selection in Lithuanian and clients are selecting contractors according to the tender price only [15].

The Analytical Hierarchy process (AHP) as a decision support tool was used for the contractor selection. Six main criteria were identified: financial capability, past performance, past experience, resources current workload and safety performance. Questionnaires were used to assign the importance weight of each criterion. The results showed that past performance was the most important criteria that affect the contractor selection, while the current workload was the least important criteria. moreover, a hypothetical case study was conducted where three bidders were competing for awarding a contract [19].

The Utility theory as a multi-criteria technique was used to identify the best contractor who has the ability to perform the work. The main technical criteria were: financial soundness, technical ability, bid amount, management capability, health and safety and reputation. A number of five contractors were competing for awarding the contract of a multi-story building as a hypothetical case study. The results showed that the contractor that submitted the lowest bid price was ranked third which showed that the bid price wasn't the only significant factor [20].

## 3 METHODOLOGY

### 3.1 Research Method

Data collection technique was done by an online questionnaire survey which was published on "Esurveycreator". Questionnaires were sent to project managers, consultants, company executives and tender evaluators through "LinkedIn" (Professional Internet Network) by sending a message to each respondent attached with the link of the online questionnaire. The following keywords were used to search for the participants: Bid evaluation- Bid estimation- Bids- Construction consultant- Project manager- Construction company executive- C.E.O

### 3.2 Literature Review

The main target throughout the reading of all the review stage was to identify the main technical and financial criteria that are used to evaluate the contractors, and to understand how tenders are evaluated in different countries.

the criteria that the tender evaluators or the bid specialized used to evaluate the contractor's technical proposal were divided into six groups, each group contains its sub-criterion as follows:

1- Financial soundness: liquidity, fixed and current assets, balance sheet, banking arrangement and bonding and credit rating.
2- Management capability: current workload and ability to handle current projects, Management knowledge, BIM implementation, scheduling and cost control plan and past performance.
3- Experience: Last five years' experience, level of technology, the complexity of executed work, performed work of similar project and experience of technical personnel.
4- Resources: availability of owned construction equipment, small tools and construction equipment, the testing equipment as quality assurance, availability of supervisors, availability of skilled labors.
5- Health & safety: Experience modification rating (EMR), OSHA incident rate, safety management accountability, experience in handling dangerous substances and experience in noise controlling.
6- Reputation: past failure to perform a contract, Past relationship between the contractor and the owner, Time taken to accomplish a work compared to the contract duration, Contracts not renewed due to failure to perform in accordance with the terms of the contract, past and recent status regarding legal suits or claims, reason for recent debarment (if any) and

previous financial penalties due to failures to perform the terms of a contract (if any).

## 4 Data Collection

### 4.1 Content of the Questionnaire

The questionnaire first section was "personal information" about the participant himself, such as: the profession of the participant whether it's consultant, project manager, C.E.O or tender evaluator, also questions related to years of experience and the type of sector that the participant works for were involved in the questionnaire. "Firm-related questions" was the 2nd section were company executives, C.E.O and tender evaluators only have the right to answer the question as the section was mainly about how tenders are evaluated in Egypt. "The participants point of view" was the 3rd section where the technical criteria that are used to evaluate the contractor were divided into 6 groups as follows: financial soundness, management capability, experience, resources, health & safety and reputation. The respondents were politely requested to assign the importance of the criterion relative to other criterion based on their experience using a nine-point scale which was developed by Saaty (1980) as shown in table 1.

TABLE 1
SAATY PREFRENCES SCALE

| Intensity | Definition |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance |
| 5 | Strong importance |
| 7 | Demonstrated importance |
| 9 | Absolute importance |
| 2,4,6,8 | Intermediate values between two adjacent judgment |

### 4.2 Challenges Faced During the Reasearch

1- It wasn't so easy to place a meeting with project managers or consultants that work for public sectors because an appointment had to be made first.
2- It was really hard to meet up with tender evaluators or bid specialist.
3- Some of project managers and consultants refused to fill in the online questionnaire.

## 5 Questionnaire Data Analysis

### 5.1 Method of Analyzing the Data

- Calculate the geometric mean for each sub-criterion to aggregate the participants' opinion by using the following equation:

$$\sqrt[n]{X1 * X2 * \dots * Xn} \qquad (5.1)$$

Where:
n = Number of participants.
x = Participant response.

- Form **the pairwise comparison matrix** for each group by forming (n × n) matrix, where "n" is the total number of the sub-criterion in one group of the six groups. The top and the left side of the matrix lies the sub-criterion label.
- Set the diagonal of the matrix to 1 and fill each cell by its corresponding geometric mean obtained from the survey.
- Calculate the summation of each column in the comparison matrix.
- Divide each score by the sum of its column to form **the normalization matrix**.
- Calculate the average of each row in the new matrix (normalization matrix) to obtain the priority vector weight of each criterion.

### 5.2 Consistency Check of the Data

1- In the pairwise comparison, Multiply the **relative importance** columns by the **priority vector** column to form a new matrix.
2- Calculate the summation of each row to get the **consistency** column.
3- Divide the consistency column by the priority vector column.
4- Calculate the average of the new column (Consistency/Priority vector) to obtain (**$\lambda$ max**).
5- Calculate the value of the consistency ratio.
6- The inconsistency is acceptable if the consistency ratio is smaller than or equal 0.10 according to Saaty (1980), otherwise, the subjective judgment should be revised.

The consistency ratio can be calculated using the following formula (Saaty, 1990):

CR=CI/RI (5.2)

Where:
CR, Consistency Ratio.
CI, Consistency Index.
RI, Random Index.

$CI = (\lambda_{max} - n) / (n-1)$ (5.3)

### 5.3 Convert the Technical Scroe into Price

After several meetings with tender evaluators and company executive to completely understand how exactly tenders are evaluated in Egypt, a method was developed to convert the contractor's technical score into money based on the facts that; tender evaluators don't award the contract to the contractors who don't get or exceed the min technical required score and bid prices have to be accepted by the company, where bid prices mustn't be lower or higher than the project estimated cost by a specific percentage to protect the owner from paying extra money if it's higher and to make sure that the contract is reliable and can be performed according to the plans if it's lower. Therefore, the lowest accepted bid price (as price) equals to minimum technical score (as technical), where all the tender evaluators and company executive agreed on fact that if a contractor got the min technical score and he has the lowest accepted bid price, the contract would be awarded to him

directly. The next step is to consider how high the technical proposal of the qualified contractor is by determining the technical equivalent price (TEP) which is the conversion of the contractor's score into price.

the TEP is a percentage of the lowest accepted bid price, so that the participants were asked to assign a percentage of lowest bid price if the contractor got a technical score equals to 1.5 of minimum required score, 2 of the minimum and 3 of the minimum score. so, three results were expected from each participant. After that the participants' responses were located on the x-y plan, where "X-axis" represents the technical score and "Y-axis" represents the percentage of the lowest bid price, in addition to the reference point which is "minimum technical required score" that has a corresponding value of 0% of the lowest bid price, as if the contractor didn't get the minimum technical score, he would be disqualified and if he got the exact value of the minimum score, his technical proposal wouldn't worth price to the evaluators as it's obligatory to get the minimum score, so that the contractors have to exceed the minimum technical score to take the advantages of the TEP and to be able to compete for awarding the contract. Finally, a regression analysis was done to aggregate the participants' opinion and to determine the TEP equation for each project scale.

The Technical Equivalent Price (TEP) is then subtracted from the contractor's submitted bid price to obtain a final bid price which is the best representation of the contractor's technical and financial proposal. If the contractor's bid price is lower than approved price range, the contractor will be disqualified to avoid the unreliable contracts, and if it's higher, the contractor will be qualified as his TEP might be high enough to decrease his final bid price

## 6 Questionnaire Reults

### 6.1 Respondants' General Information

Throughout the questionnaire it was found that 41% of the participants were project managers, 33.3% were consultants, 15.2% were tender evaluators and 10.5% where C.E.O & company executive with different experiences.

The participants have been working for different types of sectors public or private. 68.6% of the results were obtained from private sectors and 31.4% from public sectors. More than 50% of the participants agreed on that the bidding type whether it's selective, open or negotiable depends mainly on the project scale. 63% of the participants prefer the methodology of choosing the lowest bid price of the technically approved contractors.

### 6.2 Priority Vector of the Technical Sub-Criteria

The below graphs show priority vector for each criterion. the geometric mean was used to aggregate the participants' opinion.

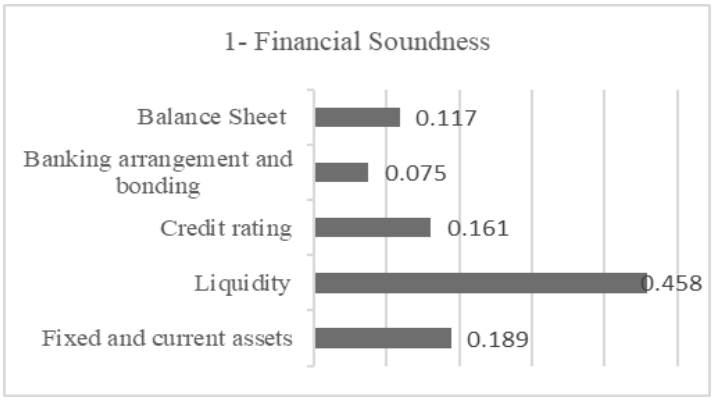



Fig. 1: Priority vector of the sub-criteria (financial soundness)

Results showed that "liquidity" has the highest priority vector as it got 0.458 which indicates that the construction projects depend mainly on the source of finance. "Fixed & current asset" ranked 2nd with a score of 0.189, followed by "credit rating" and "balance sheet", while "Banking arrangement and bonding" was found to be the least important among all the financial soundness sub-criteria.

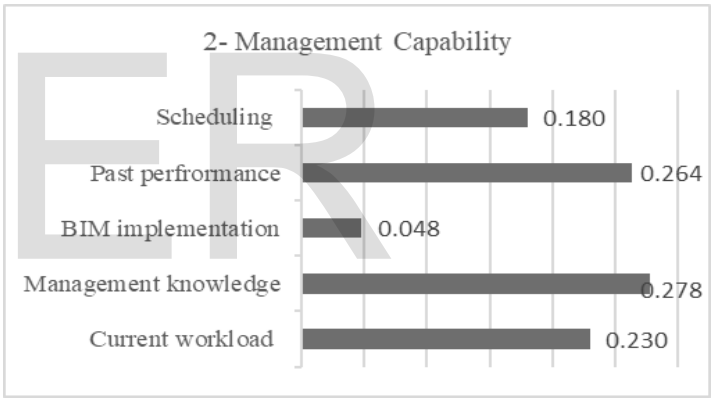



Fig. 2: Priority vector of the sub-criteria (Management Capability)

Among the management capability sub-criteria, "Management knowledge" was found to be the most important criteria, followed by "past performance and quality" with a priority weight of 0.264. while "current workload and ability to handle the current projects" placed the 3rd rank. "BIM Implementation" was found to be extremely neglected while evaluating the technical proposal of the contractor as it got a weak priority value of 0.048 which shows that it hasn't any effect on the technical success of the contractor in Egypt.

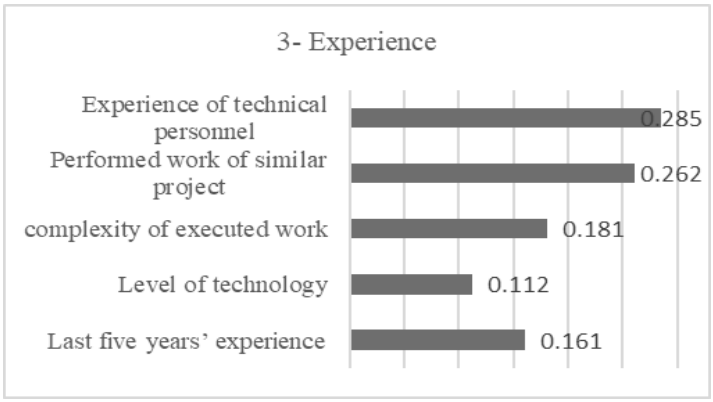



Fig. 3: Priority vector of the sub-criteria (Experience)

Contractor experience is one of the key factors that helps the contractor to award the contract. "experience of technical personnel" is the most important sub-criteria in the experience section that the evaluators put their eyes on while evaluating the contractor technical proposal as it got a priority weight of 0.285. "Performed work of similar projects" placed the 2nd rank with a score of 0.262 followed by "complexity of executed work". "Level of technology" placed the last rank.

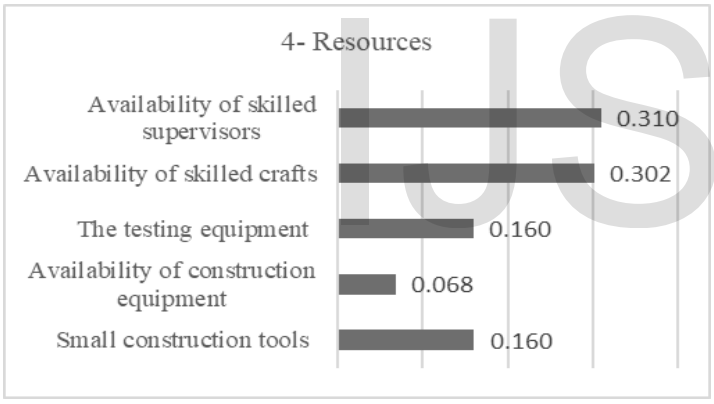



Fig. 4: Priority vector of the sub-criteria (Resources)

"Availability of skilled supervisor" was found to be the most important criteria with a priority vector of 0.310, followed by "availability of skilled crafts" with a priority vector of 0.302. "the testing equipment as quality assurance" placed the 3rd rank, followed by "small tools for construction", while "owned construction equipment" was the least important in the resources section as it got 0.068.

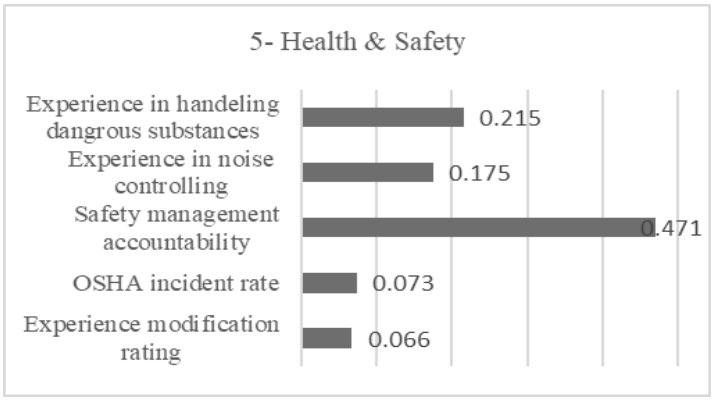



Fig. 5: Priority vector of the sub-criteria (Health & Safety)

"safety management accountability" was found to be the most important sub-criteria as it got 0.471. The difference between the 1st and the 2nd rank was 0.256 which is a great value to be considered to "safety management accountability". "EMR & OSHA incident rate" were found to be the least important sub-criteria.

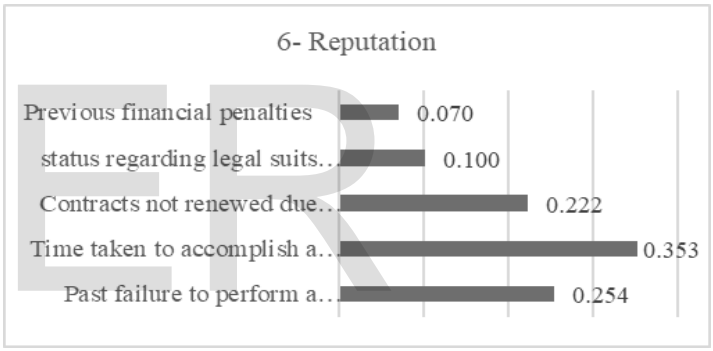



Fig. 6: Priority vector of the sub-criteria (Reputation)

For the participants, "time taken to accomplish the work" has a great effect on the technical success of the contractor as it got a priority vector of 0.353 and ranked 1st, moreover the evaluators consider "contract not renewed due to failure" as an important sub-criteria while evaluating the contractor, "Past and recent status regarding legal suits or claims" and "Previous financial penalties" were found to be the least important sub-criteria while evaluating the contractor's reputation.

### 6.3 Importance Weight of the Main Technical Criteria

To complete the process of evaluating the contractors' technical proposal, it was necessary to determine the importance weight of the main criteria based on the project scale (table 2). The participants were asked to assign the importance weight of each criteria in percent so that the summation of the percentage would to be 100%.

TABLE 2
IMPORTANCE WEIGHT OF THE MAIN TECHNICAL CRITERIA

| Project Scale / Criteria | ≤ 5M | > 5M & ≤ 100M | > 100M & ≤ 250M |
|---|---|---|---|
| Financial Soundness | 47.0% | 38.5% | 34.0% |
| Management Capability | 14.0% | 13.6% | 15.3% |
| Experience | 14.7% | 16.1% | 15.5% |
| Resources | 14.5% | 17.8% | 19.9% |
| Health & Safety | 4.8% | 6.6% | 7.5% |
| Reputation | 5.1% | 7.6% | 8.0% |

| Project Scale / Criteria | > 250M & ≤ 500M | > 500M |
|---|---|---|
| Financial Soundness | 29.8% | 22.0% |
| Management Capability | 15.0% | 16.9% |
| Experience | 14.8% | 16.0% |
| Resources | 21.8% | 24.7% |
| Health & Safety | 9.0% | 10.3% |
| Reputation | 9.6% | 10.0% |

### 6.4 Determining the Technical Equivalent Price Equation (TEP)

The TEP is a percentage of the lowest accepted bid price, so that the participants were asked to assign a percentage of lowest bid price if the contractor got a technical score equals to 1.5 of minimum required score, 2 of minimum and 3 of minimum. so, three results were expected from each participant, after that, a regression analysis was done to determine the TEP equation as shown in (6.1) for each project scale. Table (3) shows the variables of the TEP equation.

$$TEP = Lowest\ Bid\ Price * [1- (C_1Y^3 + C_2Y^2 + C_3Y + L)] \quad (6.1)$$

TABLE 3
VARIABLES OF THE TEP EQUATION

| *Project Scale ≤ 5M (EGP)* | |
|---|---|
| $C_1$ | $= -20638x^3 + 13191x^2 - 2833.6x + 208.75$ |
| $C_2$ | $= 8384x^3 - 5542.2x^2 + 1259.5x - 103.42$ |
| $C_3$ | $= -771.07x^3 + 539.74x^2 - 136.86x + 14.843$ |
| L | =0.63 |

| *Project Scale > 5M & ≤ 100M (EGP)* | |
|---|---|
| $C_1$ | $= -28140x^3 + 17987x^2 - 3863.8x + 284.65$ |
| $C_2$ | $= 11104x^3 - 7343.2x^2 + 1669.5x - 137.12$ |
| $C_3$ | $= -14287x^3 + 8667.3x^2 - 1735.9x + 118.35$ |
| L | =0.56 |

| *Project Scale > 100 M & ≤ 250 M (EGP)* | |
|---|---|
| $C_1$ | $= 11256x^3 - 7195x^2 + 1545.6x - 113.86$ |
| $C_2$ | $= -3422.4x^3 + 2262.3x^2 - 514.13x + 42.212$ |
| $C_3$ | $= 100x^3 - 70x^2 + 17.75x - 1.925$ |
| L | =0.995 |

| *Project Scale > 250M & ≤ 500M (EGP)* | |
|---|---|
| $C_1$ | $=3752x^3 - 2398.3x^2 + 515.18x - 37.954$ |
| $C_2$ | $=-342.4x^3 + 226.32x^2 - 51.428x + 4.222$ |
| $C_3$ | $=-142.13x^3 + 99.52x^2 - 25.241x + 2.7377$ |
| L | =0.89 |

| *Project Scale > 500M (EGP)* | |
|---|---|
| $C_1$ | $= -15942x^3 + 10190x^2 - 2189x + 161.27$ |
| $C_2$ | $= 6416.8x^3 - 4241.7x^2 + 963.97x - 79.147$ |
| $C_3$ | $= -605.33x^3 + 423.78x^2 - 107.47x + 11.656$ |
| L | =0.705 |

Where:
X= Minimum technical required score.
Y= Contractor's score.

## 7 HYPOTHETICAL CASE STUDY

To completely understand how the decision support model works, it was necessary to apply its procedures on a case study. All of the criteria are applied to four bidders who compete for awarding the contract of constructing a residential compound that has a scale of 250M to 500M and the project estimated cost was 400M.

It was difficult to apply the model to a real case due to the following reasons:

1- The difficulties faced to get the contractors' financial and technical proposal for a specific project as they are considered a confidential document.
2- The bidders' attributes have to be assigned in a linguistic variable form, so it was impossible to assign a linguistic variable for each attribute that reflects the actual opinion of the tender evaluator while he was evaluating the contractors.

### 7.1 How Does the Evaluation Work

1- The tender evaluator or the person who's responsible for awarding the contract has to read the technical proposal of the contractor well, then start to assign one linguistic variable using table (4) for each sub-criterion based on the contractor technical proposal.
2- The "min. bidder" column in the tender evaluation form as in table (5) is a dummy bidder, where the tender evaluator has to assign the minimum required attributes based on the project scale and requirements. So, the score of the dummy contractor represents the minimum technical required score.

TABLE 4
CHANGE THE LINGUISTIC VARIABLES INTO NUMBERS

| General Definition | Abbr. | Penalties Definition | Problems Definition | Intensity |
|---|---|---|---|---|
| Very Poor | V.P | Not Accepted | Not Accepted | **1** |
| Poor | P | Severe Penalties | Sever Problem | **2** |
| Moderately Poor | M.P | Very high Penalties | Major problem | **3** |
| Fair | F | High Penalties | Moderately major | **4** |
| Moderately Good | M.G | Moderately high | Fair | **5** |
| Good | G | Fair | Moderately minor | **6** |
| Very Good | V.G | Moderately low | Minor Problem | **7** |
| Excellent | Exc. | Low Penalties | Not at all a problem | **8** |
| Outstanding | O.S | Very low Penalties | No Recorded Event | **9** |

TABLE 5
BIDDER EVALUATION FORM

| Attributes | Min. Bidder | Bidder #1 | Bidder #2 | Bidder #n |
|---|---|---|---|---|
| *1- Liquidity* | | | | |
| Sub-Criterion 1 | V.G | G | P | V.P |
| …. | …. | …. | …. | …. |
| Sub-Criterion 5 | F | Exc. | M.G | O.S |
| *2- Management Capability* | | | | |
| Sub-Criterion 1 | G | V.P | F | V.G |
| …. | …. | …. | …. | …. |
| Sub-Criterion 5 | V.P | V.P | G | V.G |
| *3- Experience* | | | | |
| Sub-Criterion 1 | M.G | M.P | M.G | F |
| …. | …. | …. | …. | …. |
| Sub-Criterion 5 | P | V.P | G | Exc. |
| *4- Resources* | | | | |
| Sub-Criterion 1 | M.G | O.S | V.P | G |
| …. | …. | …. | …. | …. |
| Sub-Criterion 5 | V.P | G | V.G | G |
| *5- Health & Safety* | | | | |
| Sub-Criterion 1 | V.P | G | F | O.S |
| …. | …. | …. | …. | …. |
| Sub-Criterion 5 | V.G | G | V.P | G |
| *6- Reputation* | | | | |
| Sub-Criterion 1 | P | V.G | G | V.G |
| …. | …. | …. | …. | …. |
| Sub-Criterion 5 | V.P | V.P | G | V.G |

3- convert the linguistic variables into numbers (table 4) using a nine-point scale which was developed by Saaty (1980).
4- if the contractor forgot to submit a specific technical detail, assign a value of 0.0001 for this sub-criterion which means that he would get priority vector of zero for this sub-criterion.
5- Start to analyze each sub-criterion separately by forming a pairwise comparison matrix for each sub-criterion.
6- 6 main technical criteria were included in this research, each main criterion contains 5 sub-criteria, so that a number of 30 matrices are expected to be formed.
7- To form a pairwise comparison matrix, form (n × n) matrix, where "n" is the number of the competitive contractors including the dummy contractor.
8- The top and the left side of the pairwise comparison matrix lies the bidders label.
9- Divide (Sub-criterion row, 1st column) over each value in the same row to form the first row in the pairwise comparison matrix.

10- To form the 2nd row, divide (Sub-criterion row, 2nd column) over each value in the same row
11- Repeat until all rows' values are obtained.
12- Calculate the summation of each row to get the summation column.
13- Calculate the summation of the summation column and divide each value in this column by the summation of the column to get the normalized value which is called the priority vector which shows how good the contractor is in this sub-criterion.
14- By finishing step number 13, each contractor priority vector for one sub-criterion is assigned.
15- Repeat until all the pairwise comparison matrices are formed (30 matrices are expected).
16- For each bidder, the main criterion total score has to be assigned, where "5" represents the number of the sub-criterion.

$$Bidder's\ Main\ Criterion\ Score = \sum_{i=1} (Sub-Criterion\ Priorty\ Vector * Bidder's\ Priorty\ Vector)$$

17- Repeat the previous steps to determine the score of each main technical criterion for each bidder.
18- Calculate the bidder technical score, where "6" represents the number of the main technical criteria (financial soundness, management capability, experience, resources, health & safety and reputation).

$$Bidder\ Technical\ Score = \sum_{i=1} (Bidder's\ Main\ Criterion\ Score * Importance\ Weight\ of\ the\ Main\ Criterion)$$

19- Convert the contractors' technical score into price by calculating the TEP for each contractor using equation (6.1).
20- Subtract the TEP value from the bidder's bid price to get the final bid price.
21- The contractor who has the lowest final bid price is recommended to be the best-value contractor who has a combination of the best technical and financial proposal.

After calculating each contractor technical score that can be calculated using the TEP equation (table 2). it's found that the min. technical required score for this project is 0.180, so all the bidders that got lower than this score will be technically disqualified such as bidder #1 as he got 0.167, while bidder #4 has the best technical ability with a score of 0.235. bidder #2 got 0.222 and bidder #3 got 0.195.
The next step is to check whether there's at least one accepted bid price or not, where bid prices mustn't be lower or higher than the project estimated cost by 18%, otherwise the project estimated cost has to be recalculated, then exclude the contractors who submitted a bid price lower than the project estimated cost by 18% to make sure that the contract is reliable and can be performed according to the plans. After that, convert the contractor's technical score into price by calculating the Technical Equivalent Price (TEP), and then subtract this value from the bidder's bid price to get a final bid price.

TABLE 6
FINAL BID PRICE

| Bidder Label | Bid Price (EGP) | Technical Score | TEP | Final Bid Price |
|---|---|---|---|---|
| Bidder #1 | 409 M | 0.167 | Disqualified | 0.0000 |
| Bidder #2 | 416 M | 0.222 | 9.7567 M | 406.24 |
| Bidder #3 | 411 M | 0.195 | 3.5296 M | 407.47 |
| Bidder #4 | 425 M | 0.235 | 12.8082 M | 412.19 |

The result of the hypothetical case study showed that the lowest final bid price is 406.243 M, so it's recommended to choose **Bidder #2** however, his submitted bid price wasn't the lowest but he has the best combination of the technical and financial ability for the proposed project scale.
This decision support model is only a recommendation for the most suitable contractor who has the ability to accomplish the work according to the plans and to fulfill the owner satisfaction in the same time, as the final decision is taken by the person who's responsible for awarding the contract.

### 7.3 Contractor Selection Software

The software works as shown in figure (7), the 1st step is to check whether the contractor got or exceed the minimum technical score or not, cause if he didn't, he would be technically disqualified, then the qualified contractors are moved to the 2nd step which is the financial evaluation (if the user choose technical and financial evaluation). The software has to check if there's at least one accepted bid price which
means that at least one of the submitted bid shouldn't be larger or lower than the project estimated cost by 18%. if there's not accepted bid price the software generates a report informing the user that the project estimated cost has to be recalculated because all the submitted bid has unexpected price value. The software starts to exclude the contractors who submitted a bid price lower than the project estimated cost by 18% to protect the owner or the client from the unreliable contracts. finally, the software starts to calculate the technical equivalent price (TEP) for each contractor to subtract this value from the submitted bid price to obtain a final bid price, the software recommends the lowest final bid price as the best contractor and the contract should be awarded to him.

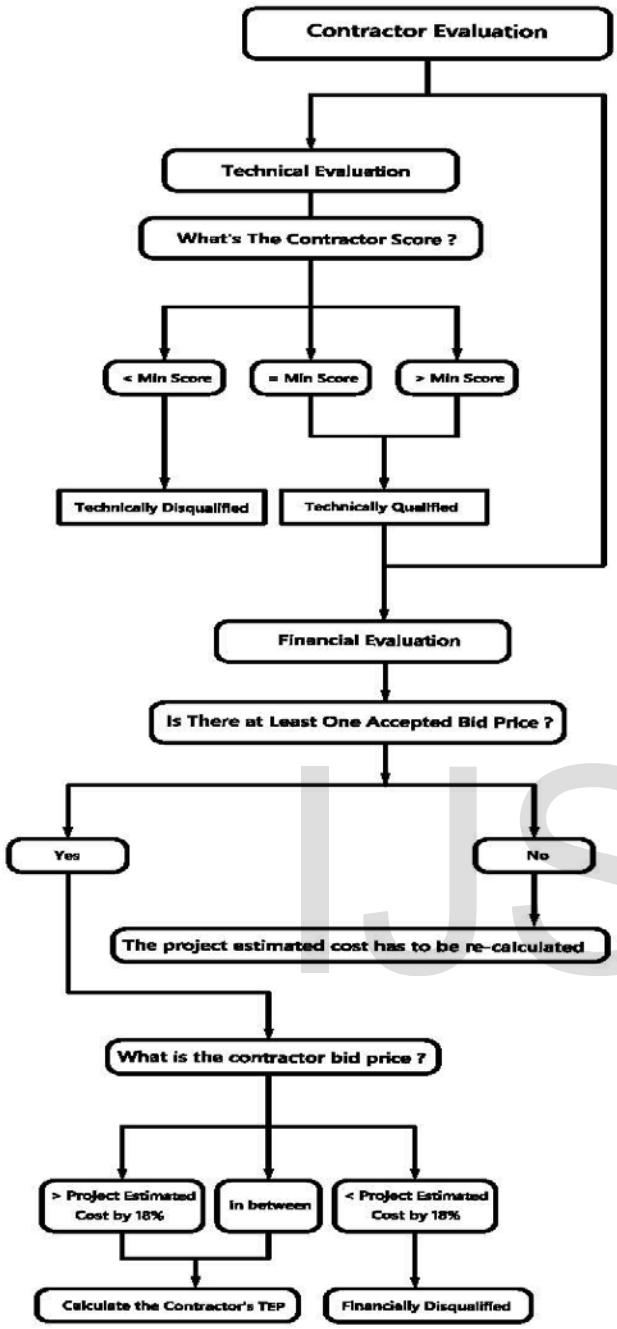



Fig. 7: Contractor selection flowchart

The 1st step the tender evaluator or the user has to do is to define the following (figure 8):

- Company Name: the name of the company which announced the tender.
- Project Scale: the project scale that the company announced, and can be assigned according to the project estimated cost. The user can choose between 5 different project scales.
- Evaluation method: there are two types of evaluation, whether to evaluate the contactors technically only or to evaluate the contractors technically and financially, so that the bid prices and the project estimated cost are considered.
- No# of bidders: the total number of the competitive contractors.

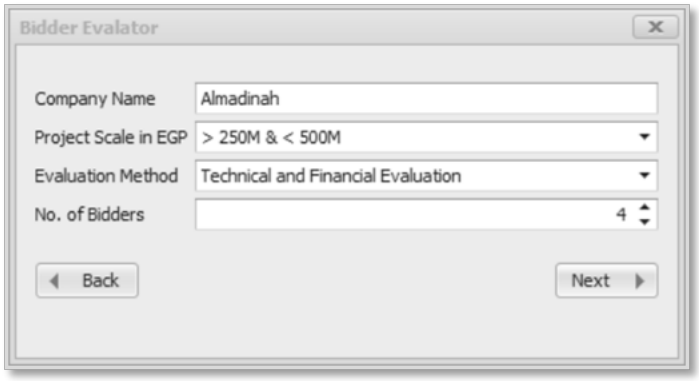



Fig. 8: Software startup menu

As defined before, the technical criteria that are used to evaluate the contractor were divided into 6 main groups, each group contains its sub-criterion, so that the evaluator or the user has to assign one linguistic variable for each sub-criterion. The red frame shown in figure (9) shows the main technical Criteria, while the brown frame shows the section where the user has to insert the different bid prices of the contractors. The blue frame as in figure (10) represents the minimum requirements that the user requires and it varies according to the project scale and requirements, so this column represents the minimum technical required score, while the yellow frame (figure 10) shows the number of the competitive contractor where the user has to assign the most suitable description for each sub-criterion based on their submitted technical proposal. To finalize the process of the evaluation, the project estimated cost has to be defined as shown in the green frame.

The final step is to press the "Analyze" button to allow the model to analyze the contractors and give a clear recommendation about the best one, then press "show results" button at the top right of the interface of the model to show the detailed report about the tender.

The user can easily add or remove bidders by pressing the related buttons at the top left of the menu bar. The data of the minimum contractor can be exported to be able to use it in the future projects, also the data can be imported by pressing "Import Min. Bidder" button.

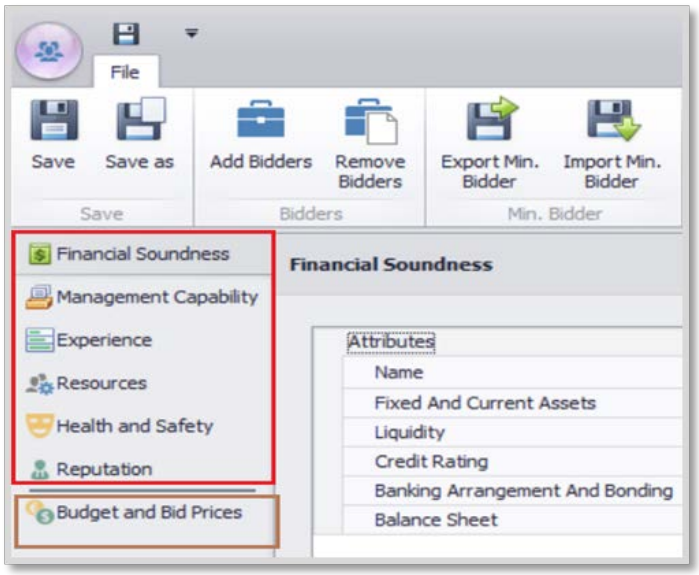
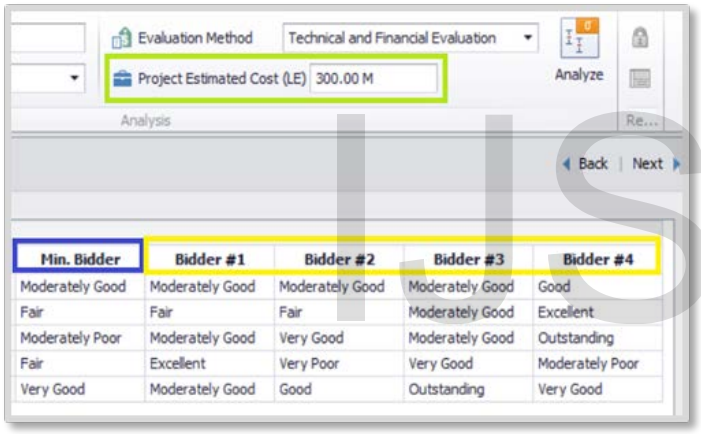



Fig. 9: User interface (a)




| Min. Bidder | Bidder #1 | Bidder #2 | Bidder #3 | Bidder #4 |
|---|---|---|---|---|
| Moderately Good | Moderately Good | Moderately Good | Moderately Good | Good |
| Fair | Fair | Fair | Moderately Good | Excellent |
| Moderately Poor | Moderately Good | Very Good | Moderately Good | Outstanding |
| Fair | Excellent | Very Poor | Very Good | Moderately Poor |
| Very Good | Moderately Good | Good | Outstanding | Very Good |

Fig. 10: User interface (b)

## 8 Conclusions

1. Financial soundness has a great effect on the technical success of the contractors for projects scale <5 M as it weighs 47% of the total technical evaluation according to the survey.
2. "BIM implementation" is the least important sub-criteria among "management capability" sub-criteria which means that tender evaluators in Egypt don't consider it as one of the key factors for contractor selection.
3. "Past failure to perform a contract" was found to be the most important sub-criterion while evaluating the contractors' reputation.
4. The evaluation committee gives a high importance weight to "Availability of skilled supervisor".
5. The contractor's high management knowledge such as site organization, coordination between the contractors and the engineers…Etc. helps him to increase his technical score significantly.
6. Awarding the contract based on the lowest bid price is not always effective. Clients tend to award the contract for the contractor who has submitted the lowest bid price, but the technical proposal should to be considered.
7. Public companies in Egypt usually choose the lowest bid price as if they didn't, they might be charged of wasting the public fund.
8. In order to achieve the aim of a construction project, qualified contractors have to be accurately chosen for the execution of the construction works. Thus, their technical ability must be evaluated by determining the technical equivalent price TEP for each contractor.
9. Considering the project scale is important while evaluating the contractor so that the technical ability of the contractor has to be increased when the project scale increases to be able to perform the work according to the contract terms and conditions.
10. Analytical hierarchy process AHP as a decision-making tool has shown a great success while comparing different alternatives.
11. The proposed model can be applied to any number of contractors and can be used for the prequalification stage by assigning the minimum technical required score for this stage.

### 8.1 General Recommendation

1. The tender evaluator or the user has to read the contractors' technical proposal well first to be able to assign the linguistic variables while using the contractor selection software.
2. The linguistic variable that the tender evaluator or the user assigns for each sub-criterion should be assigned on the basis of fairness and equality.
3. Each company has to define its own linguistic variable policy by setting a range of each linguistic variable for each sub-criterion to avoid bias and to make sure that the user chooses the best linguistic variable that describes the contractors accurately based on the defined list and rules of the company.
4. Evaluating the tender based on the lowest bid price doesn't always guarantee the accomplishment of the work according to the terms and conditions of the contract, so that a full and precise assessment of the contractor's technical and financial ability should be done.
5. Considering the project scale is important while evaluating the contractor so that the technical ability of the contractor has to be increased when the project scale increases to be able to perform the work according to the contract terms and conditions.

### 8.2 Recommendations for Future Studies

More researches on contractor selection should be done to cre-

ate more guidelines and to be updated to the most important criteria that are used to evaluate the contractors in Egypt. Increasing the number of the participated tender evaluators or company executives may lead to improve the results as they are the directly responsible for awarding the contract. Also making a comparision between different methodologies that are used to evaluate the contractor may also help to improve the process of selecting the best contractor. Moreover, similar research should be implemented in various regions or cities of Egypt to provide more reliable data which is required to carry out studies for each specific type of construction projects, including: highways, dam construction projects, utilities and etc.

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