Management Model for Evaluation and Selection of Engineering Equipment Suppliers for Construction Projects in Iraq

Dr. Kadhim Raheem Erzaij
Lecturer
College of Engineering-University of Baghdad
kadhim1969@yahoo.com

Aula Sakban Bidan
Graduate Student
College of Engineering-University of Baghdad
eng_aula2010@yahoo.com

ABSTRACT

Engineering equipment is essential part in the construction project and usually manufactured with long lead times, large costs and special engineering requirements. Construction manager targets that equipment to be delivered in the site need date with the right quantity, appropriate cost and required quality, and this entails an efficient supplier can satisfy these targets. Selection of engineering equipment supplier is a crucial managerial **process** .it requires evaluation of multiple suppliers according to multiple criteria. This process is usually performed manually and based on just limited evaluation criteria, so better alternatives may be neglected. Three stages of survey comprised number of public and private companies in Iraqi construction sector were employed to identify main criteria and sub criteria for supplier selection and their priorities.The main criteria identified were quality of product, commercial aspect, delivery, reputation and position, and system quality . An effective technique in multiple criteria decision making (MCDM) as analytical hierarchy process (AHP) have been used to get importance weights of criteria based on experts judgment. Thereafter, a management software system for Evaluation and Selection of Engineering Equipment Suppliers (ESEES) has been developed based on the results obtained from AHP. This model was validated in a case study at municipality of Baghdad involved actual cases of selection pumps suppliers for infrastructure projects .According to experts, this model can improve the current process followed in the supplier selection and aid decision makers to adopt better choices in the domain of selection engineering equipment suppliers.

Key words: engineering equipment, supplier, construction, AHP, decision maker, model, ESEES, software.

نموذج اداري لتقييم واختيار مجهزي المعدات الهندسية في المشاريع الانشائية في العراق

د.كاظم رحيم ارزيج
مدرس
جامعة بغداد-كلية الهندسة-قسم الهندسة المدنية

علا صكبان بدن
طالب ماجستير
جامعة بغداد-كلية الهندسة-قسم الهندسة المدنية

الخلاصة

ان المعدة الهندسية هي جزء اساسي في المشروع الانشائي وتصنع عادة بفترات انتظار طويلة ،كلف عالية ومتطلبات هندسية خاصة.يطمح مدير المشروع بأن تسلم المعدات في الموقع في الموعد المحدد،الكمية الصحيحة وبالكلفة المناسبة والجودة المطلوبة وان هذا يستلزم وجود مجهز كفوء يستطيع تحقيق هذه الاهداف. ان تقييم واختيار مجهزالمعدات الهندسية يعد عملية ادارية حاسمة تتطلب تقييم لعدة مجهزين وفقا" لمعايير متعددة وان هذه العمل عادة ما يتم انجازه يدويا" ويبنى على عدد محدود من معايير التقييم وبذلك فان بدائل افضل قد يتم التغاضي عنها. تم توظيف ثلاثة مراحل من المسح الميداني شملت عدد من الشركات الحكومية والخاصة في القطاع الانشائي العراقي لغرض تحديد المعايير الرئيسية والفرعية لاختيار المجهزين و أولوياتها. المعايير الرئيسية التي تم تحديدها هي جودة المنتج، الجانب التجاري، التسليم، السمعة والمكانة و جودة النظام.

تم استخدام تقنية فعالة في عملية صنع القرار متعدد المعايير وهي عملية التحليل الهرمي بواسطة برنامج (AHP) للحصول على اوزان الاهمية للمعايير بناءا" على حكم الخبراء .

بعد ذلك تم بناء نظام ادارة حاسوبي لتقييم واختيار مجهزي المعدات الهندسية(ESEES) اعتمادا" على النتائج المستحصلة من برنامج (AHP) .هذا النموذج تم التحقق منه بتطبيقه على حالة دراسية (أمانة بغداد) متضمنة حالات واقعية لاختيار مجهزي مضخات لمشاريع بنى تحتية. وفقا" للخبراء فان هذا النموذج يمكن ان يحسن الطريقة الحالية المتبعة في اختيار المجهزين ويدعم صانعي القرار في تبني خيارات افضل في مجال اختيار مجهزي المعدات الهندسية.

الكلمات الرئيسية : معدات هندسية ،مجهز ، انشاء، AHP، صانع قرار، نموذج ،ESEES ، برمجيات

1. INTRODUCTION

Selection of engineering equipment suppliers is one of the most critical decisions taken by procurement manager. It is not an easy process and generally consists of four stages; defining objective, formulating the selection criteria, qualifying the suitable alternatives and final selection. Many different formulas and techniques involve the determination of quantitative and qualitative factors can be used to select the best possible suppliers. Supplier selection decisions were complicated by the fact that various criteria must be considered in decisions making process **Weber et al., 1991.** According to **G3SP-ESS, 2010**, the procurers can categorize supplier selection criteria as *Mandatory* which represents the criteria that a supplier must meet in order to be on the bid list , *Preferred* refers to criteria that is not necessary to be meeting by suppliers to enter the bid list and *leading* criteria which really differentiate suppliers and will separate the exceptional suppliers from the ordinary and should have the highest weighting within the supplier selection process. Number of studies were conducted to deal with suppliers evaluation; **Ho et al., 2007** in their study, they identified what criteria that construction firms in Taiwan and Vietnam were adopted to evaluate and select suppliers. They confirmed that non-quantifiable criteria like, quality and capability to meet delivery due dates have the most important role in the selection process. **Azambuja and Chen , 2010** presented methodology of statistical procedure of cluster analysis for commercial assessment to select short list of equipment suppliers in construction projects but this technique was supported just quantitative criteria. This study aims to present a management model with a decision support tool that can aid construction firms in the selection of the best engineering equipment suppliers that satisfy project targets considering both quantitative and qualitative criteria.

2. SUPPLIERS EVALUATION AND SELECTION

The analysis of criteria for selection and measuring the performance of suppliers had been the focus of many scientists and purchasing practitioners since the 1960’s. In the recent years, many researchers in the domain of supplier selection like **Benyousif et al., 2003**, **Thanaraksakul, and**

Phruksaphanrat, **2009**, **Pal et al. ,2013** and **Abdolshah ,2013** referred to an interesting work presented by Dikson .

Dikson ,1966 conducted a questionnaire and sent it to 273 purchasing organizations and managers selected from list of managers in the National Association of Purchasing Managers, which covered USA and Canada. He had received 170 mails regarding the 23 important criteria which were ranked according to the observations. The results showed that delivery, quality, performance history, and warranty policies were the most important criteria for 1960s .Thereafter, the 23 criteria in Dikson (1966) were served as principal for categorizing criteria in the consequent researches. **Pal et al. 2013** stated the various important criteria for the supplier selection such as: price, quality, delivery, performance history, warranties and claims policies, production, facilities and capacity, technical capability, financial position, procedural compliance, reputation and position in industry, desire for business, repair service, attitude, packaging ability, labor relations record, geographical location, amount of past business and reciprocal arrangement.

2.1 Identifying Potential Suppliers

This process is substantial, it is often critically important to discover new suppliers as well as develop the existing suppliers. The buyer must ensure such suppliers are qualified .The qualification processes should be performed according to the qualification criteria set on the solicitation documents. A potential supplier who does not meet the required qualifications will be rejected, and this will lead to short list suppliers.

Pre-qualification is an effective method for identifying potential suppliers to invite for tender, particularly where a large number of suppliers might be able to fulfill the organization's needs.

Some organizations pursue pre‑qualify suppliers prior to have a specific need. This can allow them to focus on specific needs at a given moment in time from a pre-qualified pool of suppliers.

To ensure that the pre-qualification process is not too cumbersome, suppliers should only be requested to provide information adequacy to satisfy the buyer on their level of competence that is sufficient to execute any future contract. Such qualifications criteria may be all or some of the following **IAPWG, 2006**:

1. Legislative requirements
2. The financial strength
3. Performance record
4. Business ethics record

5. Production capacity.
6. Experience and technical capacity

If a pre-qualification process has preceded the solicitation, just suppliers who have passed the pre-qualification would be allowed to submit offers.

2.2 Methods for Suppliers' selection

For many years, the traditional approach to select supplier has been to select suppliers based on the basis of price ,**Pal et al., 2013**. Actually, evaluation and selection of suppliers is a typical multiple criteria decision making (MCDM) that can be both qualitative and quantitative. However, as companies realized this fact, they have turned into more comprehensive multi-criteria approaches**.**

Decision aid methods are very useful tools is used to support managers making selection decisions**.** There are number of multi-criteria techniques that have been developed in operations research to aid solving selection problems.

Pal et al., 2013, in their research, summarized various supplier selection methods as shown in **Fig.1.** The most well- known (MCDM) technique which is used in various selection problems is Analytical Hierarchy Process (AHP). AHP was developed by **Saaty, 1980** as a mathematical decision making model which solved complex linear algebra problems when there were multiple objectives or criteria to be considered. It required the decision makers to provide judgments about the relative importance criterion for each decision alternatives. AHP is an effective tool dealing with complex decision making, and can aid the decision maker in setting priorities and making the best choice by reducing complex decisions to a series of pair wise comparisons; then the results were synthesized. The researcher adopted this tool in developing a model for the evaluation and selection of engineering equipment suppliers.

3. IDENTIFYING CRITERIA FOR EVALUATION AND SELECTION OF ENGINEERING EQUIPMENT SUPPLIERS

To identify which criteria are the basis for E.E supplier's selection in Iraq and their priorities, a field survey was conducted in number of public and private companies in Iraqi construction sector. In the first stage, some of criteria were identified by personal interviews with top senior managers. From literature review and interviews with specialist, the required criteria for evaluation and selection suppliers were identified. A closed questionnaire form contained the identified criteria were presented to (44) of the respondents to identify the degree of importance

of each criteria . These criteria were reordered as a hierarchy of five main criteria and sub criteria related to each main criterion, see **Fig.2.**

In order to get importance weights of criteria a special questionnaire form was prepared, this form based on the principle of analytical hierarchy process to get priorities of criteria.

In this form, a simple matrix was built for each of main and sub criteria. The specified criteria were placed in the matrix vertically and matched by the same criteria in a horizontal bar. To achieve this purpose ,(15) experts in the domain of evaluation engineering equipment suppliers were asked to compare the importance of criteria according to the ratios set in the questionnaire form which was based on AHP scale ,see **Table 1**.

The answers of respondents were collected, and then the average of the values given by respondents was calculated in order to get criteria priorities.

4. DEVELOPING DECISION MAKING MODEL (AHP, ESEES)

A proposed model for evaluation and selection of E.E suppliers contains two parts:

Part 1: The analytical hierarchy process (AHP) is used as a tool for support decision in selection among suppliers regarding multi criteria qualitative and quantitative criteria. Precisely, to find importance weight for criteria and sub criteria according to the results obtained from questionnaire of priorities. The results obtained from AHP are shown in **Tables 2** and **3**.
Part 2: A software model for evaluation and selection of E.E suppliers (ESEES) depending on importance weights of criteria obtained from the application of AHP developed software.

4.1 Development of a Software Model (ESEES)

The application (ESEES) has been implemented by Microsoft visual basic as a windows form with Microsoft access as the back data base. The main window is shown in **Fig.3.**
The core window in this program is named as Evaluate suppliers. It contains the list of sub criteria where the user can enter the rating of one supplier against each criterion. The values shown at the side of the ratings are calculated by multiplying the rating that evaluator has entered by the importance weight for the sub criteria and their related main criteria .These importance weights have been obtained by applying the (AHP) Software illustrated previously and saved as database in this program. The total rating of one supplier also can be shown in this window and the mathematical procedure behind this process is expressed as follows:

The researcher suggested an equation to get the total rating for one supplier, that for **n** number of main criteria and **n** number of sub criteria related to each main criterion,
Total rating for one supplier = $M_1 (s_1M_1*Rs_1M_1+s_2M_1*Rs_2M_1+\ldots\ldots+s_nM_1*Rs_nM_1) +$
$M_2(s_1M_2*Rs_1M_2+s_2M_2*Rs_2M_2+\ldots\ldots+s_nM_2*Rs_nM_2)+\ldots\ldots+$
$M_n (s_1M_n*Rs_1M_n+s_2M_n*Rs_2M_n+\ldots\ldots+s_nM_n*Rs_nM_n)$ (1)
Where:

M_1, M_2, M_n are the importance weights of the first, second, and n_{th} main criterion respectively.
s_1M_1, s_1M_2, s_1M_n are the importance weights of each first sub criterion related to the first ,second, and n_{th} main criterion, respectively .
Rs_1M_1, Rs_1M_2, Rs_1M_n are suppliers rating against each first sub criterion related to the first, second, and n_{th} main criterion, respectively.
s_2M_1, s_2M_2, s_2M_n are the importance weights of each second sub criterion related to the first ,second, and n_{th} main criterion, respectively .
Rs_2M_1, Rs_2M_2, Rs_2M_n are suppliers rating against each second sub criterion related to the first ,second, and n_{th} main criterion, respectively .
s_nM_1, s_nM_2 , s_nM_n are the importance weights of each n_{th} sub criterion related to the first ,second, and n_{th} main criterion respectively.
Rs_nM_1, Rs_nM_2, Rs_nM_n are suppliers rating against each n_{th} sub criterion related to the first ,second, and n_{th} main criterion respectively .
and, $M_1+M_2+\ldots\ldots+M_n=100\%$

$s_1M_1+ s_2M_1+\ldots\ldots+s_nM_1=100\%$

$s_1M_2+ s_2M_2+\ldots\ldots+s_nM_2=100\%$

$s_1M_n+ s_2M_n+\ldots\ldots+s_nM_n=100\%$

The entry of supplier's ratings is in a percentage form. The main steps of ESEES software approach is shown in **Fig.4**.

5. VALIDATION OF THE PROPOSED MANAGEMENT MODEL

A case study was selected to describe the results obtained from using the software. The case study chosen was Municipality of Baghdad as the fact that this organization expends large amounts of money on the procurement of engineering equipment, especially for infrastructure projects. The suggested engineering equipment for this study was (pumps). Pumps are considered a critical component in project whatever process it operates: power, destination, petrochemical, and water treatment or supply. The complete plant operation depends on the reliable performance of the main intake, cooling or seawater pumps. Two actual cases were selected for pumps procurement. The first was Sharq Dijla project for water treatment and the other was Al- Rustamiya project for sewage treatment. A team from each of Baghdad sewerage and Baghdad water directorates consisted of different qualifications was specified to evaluate the bidders regarding the sub criteria by studying the offers and analyzing the catalogues in detail.

The suggested team included; civil engineer, mechanical engineer and financial member. These engineers have sufficient experience in project requirements and required equipment.

5.1 Case study :Municipality of Baghdad -Infrastructure Projects

5.1.1 First case: Extension of sewage treatment plant at Al-Rustamiyah project:

Selection of submersible pumps with different diameters.

The actual award decision according to traditional process is shown in **Table 4** ,while **Fig. 5** shows the results obtained from applying ESEES program.

5.1.2 Second case: Extension of existing water treatment plant at Sharq Dijla project: Selection of vertical pumps supplier.

The actual award decision according to traditional process is shown in **Table 5** , while **Fig. 6** shows the results obtained from applying ESEES program.

5.2 Comparison between Traditional Method and Applying of (ESEES) Software in Supplier Selection

1. In the first case, the final result showed that EPC Company was the best supplier for submersible pumps. This result differs from the actual recommendation which was (Al Qotb Alaraby company).Based on the fact that the criteria adopted was more comprehensive and feasible for suppliers' selection. The result obtained by the proposed model is seen to be more suitable for serving the targets of project and procurement.

2. In the second case, the result obtained from ESEES shows that the bidder (Alwa company) is ranked as a top supplier. This result was similar to that obtained from actual recommendation, and that seemed reasonable as there were some criteria were not been considered by the team like (ground shipping and transport, risks, environmental benefits and innovation) because there were not sufficient details or indicators in the offers to prefer one bidder to the others.

6. CONCLUSIONS AND RECOMMENDATIONS

The major observations and conclusions can be summarized as follows:

a. The traditional evaluation process is based on criteria and importance weights decided by Ministry of Planning with limited flexibility in changing the weights as necessary. These criteria are not comprehensive and do not cover the supplying requirements and project targets.

b. The importance weights of main criteria resulted from applying AHP software showed that **Quality of product** is the most important criterion in the selection of the

best supplier, followed by **Commercial aspect**. The third place is for **Delivery and implementation** while the fourth place is received by **Reputation and position** and the last ranking is for criterion of **System quality**.

c. According to experts, the proposed model can contribute to serve the construction project management related to cost, schedule and quality requirements and successful selection can prevent later supplier related problems affecting project targets.

d. To get advantage of the proposed management model , it is recommended to:

- Provide the criteria and importance weights which are identified in this study to the procurement documents so that the tenderers take in to account when developing their offers.
- The evaluation process should be conducted by professional and experienced persons related to the supplying the required equipment.
- Specifying qualified persons to evaluate the supplier's present performance and save this rating for supporting future decisions.

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NOMENCLATURE

AHP: Analytical Hierarchy Process.

ESEES: Evaluation and Selection of Engineering Equipment Suppliers.

E.E: Engineering Equipment.

MCDM: Multiple Criteria Decision Making.

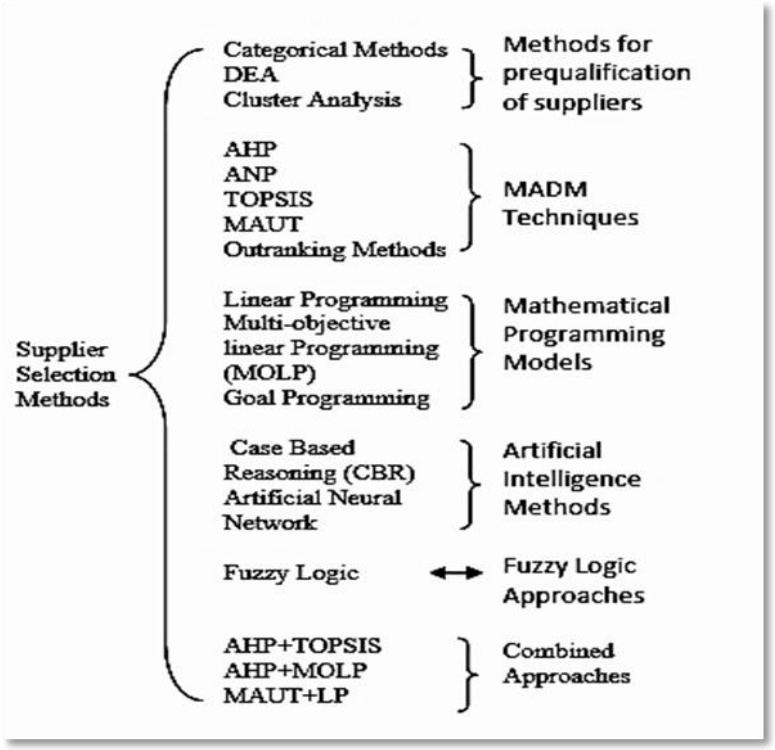

Figure 1. Various supplier selection methods, **Pal et al.,2013**.

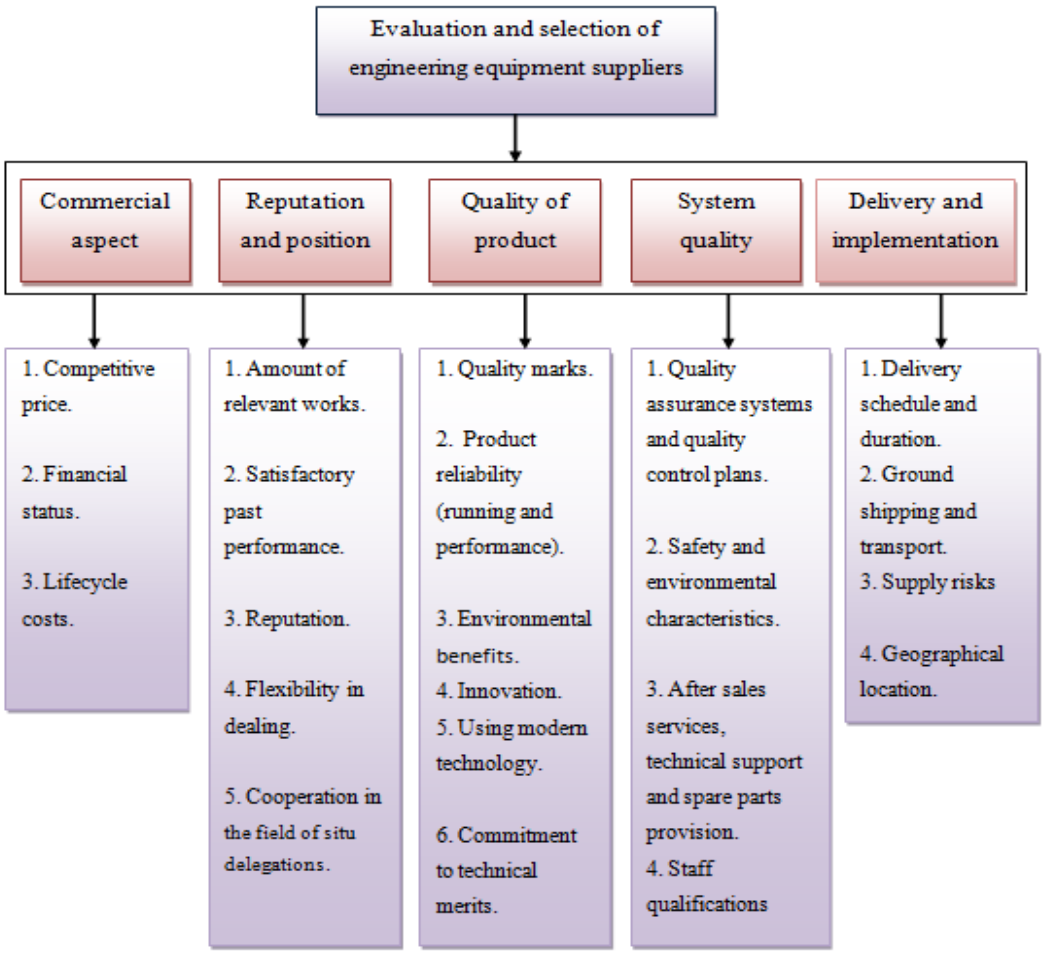

Figure 2. Hierarchy for evaluation and selection of E.E suppliers.

Figure 3. The main window of ESEES.

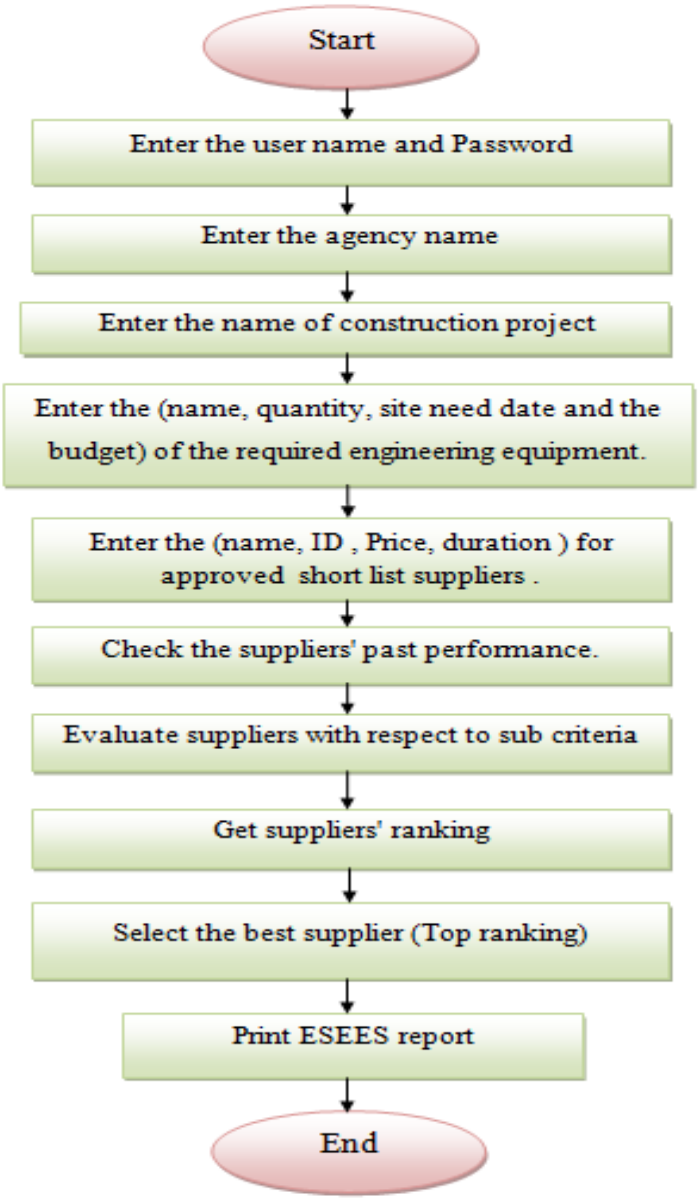

Figure 4. ESEES software approach.

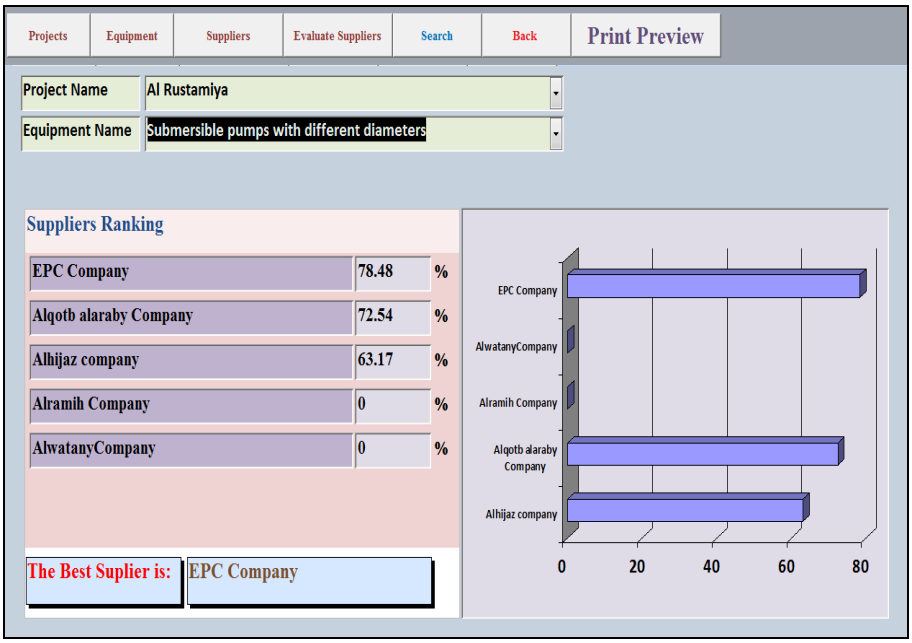

Figure 5. The final results of bidders evaluation (submersible pumps) by applying (ESEES).

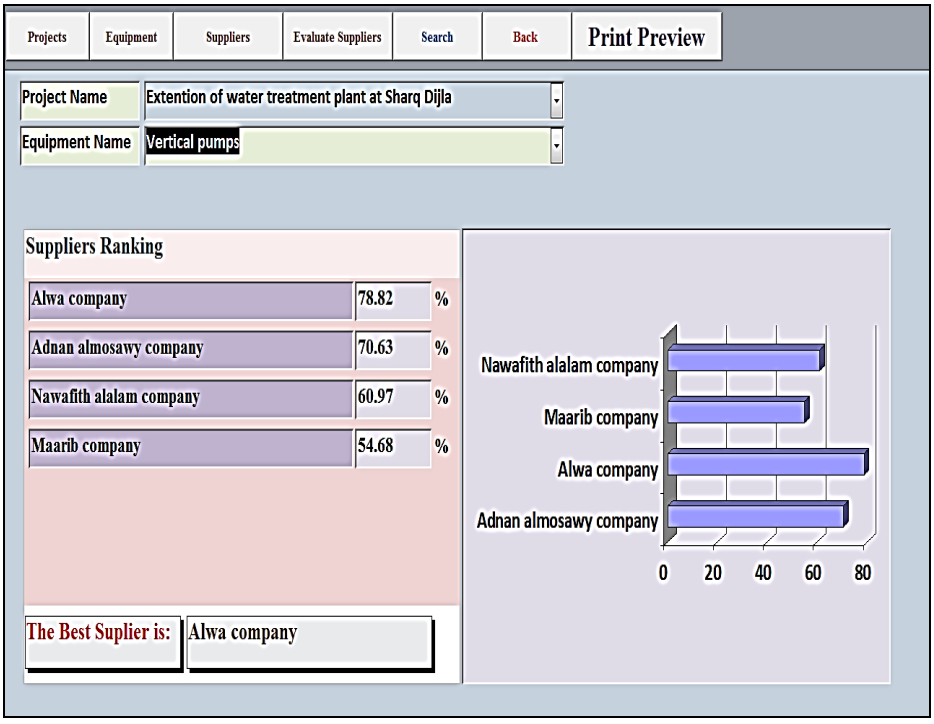

Figure 6. The final results of bidder's evaluation (vertical pumps) by applying (ESEES).

Table 1. : Scale of relative importance in AHP approach, **Saaty, 1980**.

Value of relative importance (a_{ij})	Definition
1	Equally important attributes
3	Moderate importance of one attribute over other
5	Strong importance of one attribute over other
7	Very strong importance of one attribute over other
9	Extreme importance of one attribute over other
2,4,6,8	Intermediate values between the two adjacent judgments
Reciprocal of above non- zero numbers	If an attribute is given one of the above numbers when compared with a second attribute , then the second attribute is assigned the reciprocal value when compared with the first attribute

Table 2. Ranking of main criteria according to importance weights with respect to the goal.

Weight %	Criteria	No.
39.0%	Quality of product	1
26.8%	Commercial aspect	2
16.9%	Delivery and implementation	3
10.0%	Reputation and position	4
7.1%	System quality	5

Table 3. The ranking of sub criteria according to their importance weights.

Weight %	Sub-criteria for Commercial aspect (Inconsistency = 0.05156)	No.
20.8%	Financial Status	1
66.0%	Competitive price	2
13.1%	Lifecycle costs	3
Weight %	Sub-criteria for Reputation and Position (Inconsistency = 0.02043)	No.
33.6%	Satisfactory past performance	1
23.6%	Flexibility in dealing	2
22.0%	Reputation and position	3
12.3%	Amount of relevant works	4
8.3%	Cooperation in the field of situ delegations	5
Weight %	Sub-criteria for Quality of product (Inconsistency = 0.04056)	No.

47.5%	Commitment to technical merits	1
21.2%	Quality marks (origin)	2
10.9%	Product reliability (running and performance)	3
8.4%	Environmental benefits	4
6.1%	Innovation	5
5.8%	Using modern technology	6
Weight %	Sub-criteria for System Quality (Inconsistency = 0.00156)	No.
33.0%	Staff qualification	1
28.8%	Safety and environmental characteristics	2
20.6%	Quality assurance system and quality control plans	3
17.4%	After sales services, technical support	4
Weight %	Sub-criteria for Delivery and implementation (Inconsistency = 0.06948)	No.
51.8%	Delivery schedule and duration	1
28.3%	Risks	2
9.8%	Ground shipping and transport	3
9.8%	Geographical location	4

Table 4. Actual award decision for supplying submersible pumps to Al-Rustamiyah project.

No.	Bidder	Technical aspect (60%)	Commercial aspect (40%)	Total (100%)
1	Alqotb Alaraby Company	51.5	40	91.5
2	EPC Company	56.1	32.6	88.7
3	Alhijaz Company	34.2	33.9	67.9
4	Alramih Company	Excluded		
5	Al Watany Company	Excluded		

Table 5. Actual award decision for Supplying vertical pumps to the treatment plant at Sharq Djila project.

No.	Bidder	Technical aspect (60%)	Commercial aspect (40%)	Total (100%)
1	Alwa Company	57	34.9	91.9
2	Adnan al Mosawi Company	33	37.6	70.6
3	Nawafith Alalam Company	33	36.2	69.2
4	Maarib Company	12	40	52