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Fuzzy Analytical Hierarchy Process for Embedded Risk Reduction in Selecting the Right Planning Decision

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Abstract

The aim of this work is to provide an efficient selection technique as a part of planning process to guide the decision makers to decide the preferences of one supplier over another for purchasing lab instruments in education domain. Fuzzy Analytical Hierarchy Process has used as a multi-criteria decision process, as an industrial engineering tool with certain emphasis on the qualitative aspects required to the decision makers. While the concept of degree of possibility for each criterion is used to reach its relative weights, a specific methodology created to reach the final objective decision of supplier selection. A questionnaire form was developed and distributed to five universities located in Baghdad province with a total number of 100 questionnaires. The response was very adequate. Three main criteria are adopted- supplier, instruments and service performance grade. Moreover, there are sixteen sub-criteria for evaluating three potential suppliers. The final decision is reached with almost risk-free as it relates to the qualitative aspects of experts. The conclusion reached is that local supplier has a large priority weight. Microsoft Excel is used to achieve the sequential calculations for Fuzzy AHP.

Keywords: *Supplier Selection, multi criteria, fuzzy analytical hierarchy process, risk reduction, qualitative aspects.*

1. Introduction

There is abundant analysis within the literature that describes the matter of risk reduction from different perspectives, depending on the nature of problem addressed, all can be considered as a step of the planning process. However, research in this area continues to depend on the nature of use, sensitivity, and appropriateness of different types of organizations. Therefore, dealing with this problem from the perspective of multiple criteria, and objectives are required carefully investigate to reach the goal sought by the decision maker. Hence, Supplier selection is a comprehensive problem relating qualitative and quantitative multi-criteria where risk is embedded during the decision process.

Supplier selection, as defined by Boran and et.al [1] is “the process of finding the right suppliers who are able to provide the buyer with the right quality products and/or services at the right price, at the right time and in the right quantities”. On the other hand, it is a hard problem since supplier selection is typically a multi criteria group decision-making problem involving several conflicting criteria on which decision maker’s knowledge is usually vague and imprecise.

Analytical hierarchy process (AHP) can be considered as a Multi Criteria Decision Making

(MCDM) tools to deal with risks associate with decision process. The AHP separates the judgment developed by Saaty [2] Consequently AHP importance raised from its ability to cope with both qualitative and quantitative data and spread over wide application areas as mentioned by Franek & Kresta [3].The most critical issue of AHP related to other decision making approaches is its ability to use private individual judgments of decision maker as a focus of qualitative side [4], [5].

AHP method is based on mathematical tools for the processing of personal subjective preferences of the expert or a group of experts on the pairs of relevant factors formulated as comparative matrix assessing and analyzing decisions [6]. The AHP method works on the premise that the process of making a global decision on complex tasks can be performed by separating and structuring complex tasks into many simple tasks, displaying them in the form of hierarchical structure Fig. 1. In its turn, after the hierarchical structure is formed, the pairwise comparison of assessment factors is carried out according to the importance on a lower level of the hierarchy. The results of pairwise comparisons evaluation decision into hierarchy levels and attempts to reduce the inconsistencies in human are displayed by numbers related to specific application ranging from two extreme points i.e. from starting evaluation to final one. Whereas starting means that the two evaluation factors reflected by linguistic value as equally important, while the other extreme rating reflects the fact that one assessment factor is absolutely more important than the other. While the in between these two extremes are other division of evaluation.

Next, the pairwise comparison of alternatives for each of the criteria factors is carried out. Then, the obtained estimates are translated to the next level i.e. mid-level which dealing with criteria assessment, where the aggregation of previously obtained estimates is performed [7].Thereafter, the interim assessments are transferred to the upper level of the hierarchy i.e. the level of goal /objective. The final aggregation of previous estimates is reached which reflects the resultant estimation for each alternative decision. The selection of the optimal solution is evaluated based on comparison of these estimates.

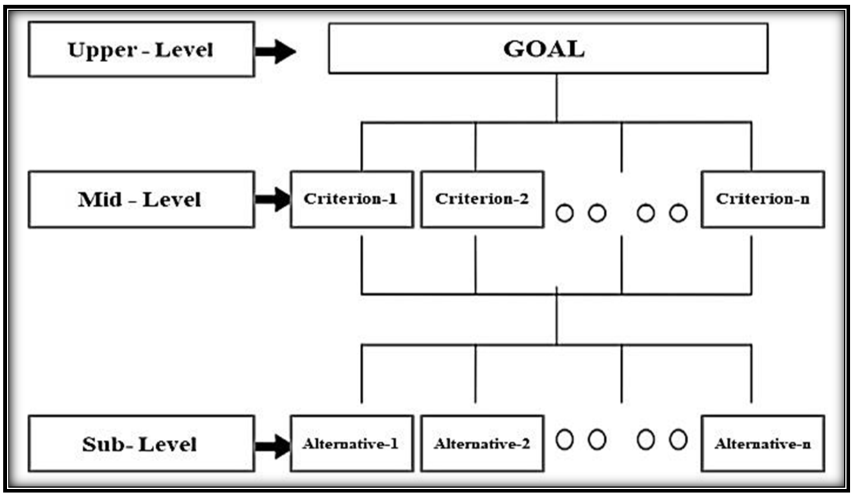

Fig. 1. AHP hierarchical structure (Oguztimur, 2011).

This paper is dealing with multi criteria decision process concentrated on selection of proper supplier for purchasing laboratory equipment required by scientific departments which facing a critical issues due to the absence of systemic scientific procedure. The current process is highly depends on personnel criteria parameters not relays on scientific formulated procedure. Since this process is carry out in a non-profit environment. Fuzzy AHP is proposed to solve such type of problem which heavily depends on the opinions of related experts in the fields. Special questionnaire format are used as a basis of the qualitative part of the proposed tool.

Rest of this work is organized as follows. In section 2, criticism of AHP is given. Section 3 presents detailed description of Fuzzy MCDP. Synopsis of related literature review is covered in section 4. Problem issues are detailed in section 5. Then Research Methodology is the focus of section 6. In section 7, numerical calculations for supplier selection problem is demonstrated. Finally results and conclusion of the work is presented in section 8.

2. Criticism of AHP

In the conventional shape of AHP, human's judgments area unit depicted as exact or crisp numbers. However, in several sensible cases the human preference model is unsure and decision-makers can be reluctant or unable to assign exact numerical.

In light of this, some shortcomings as mentioned by Kabir and et.al. [9] of the application of Saaty's AHP were heightened as follows:

1. The AHP technique is especially employed in nearly crisp decision applications.
2. Ranking of the AHP methodology is quite general. The AHP method creates and deals with a very unbalanced scale of judgment.
3. The AHP technique doesn't take into consideration the uncertainty related to the mapping of one's judgment to variety.
4. The AHP technique creates and deals with a really unbalanced scale of judgment.
5. The subjective judgment, choice and preference of decision-makers have an enormous influence on the AHP outputs.

Additionally, decision-makers need on evaluating alternatives invariably contain ambiguity and multiplicity of which means. Moreover, it has additionally recognized that the human assessment of qualitative attributes is usually subjective and therefore general.

AHP can't satisfactorily cope with the imprecision and uncertainty in to be had information and in decision maker's alternatives. Human judgments whether or not they are quantitative or qualitative have a few inherent uncertainties in realistic eventualities because of distinct non-public perceptions. Experts may additionally be reluctant to assign actual numerical values whilst evaluating parameters. In Multi criteria decision making MCDM, assessment standards are each subjective and quantitative relying upon nature. The consulted databases additionally consist of positive imprecision as a few approximations may additionally be concerned inside the instruction of this type of database. Good decision-making procedure ought to be capable of consider this normal fuzziness to keep away from deceptive consequences. Therefore, the standard AHP looks inadequate to capture the choice maker's needs expressly regardless of the wider application and ease of its concept, and can not exactly deal with this inherent vagueness and uncertainty [10]. Consequently, it's requiring the adoption of fuzzy logic with AHP method.

3. Fuzzy Multi Criteria Decision Making

In dissimilarity fuzzy multiple criteria decision-making (FMCDM) is the method of ranking the possible alternatives and choosing the most effective one by considering multiple criteria, during which the alternatives and criteria values are carried by completely different fuzzy sets belongs to fuzzy theory [11], like triangular fuzzy range [12], triangular intuitionist fuzzy range [13], and many others found in [14] [15], [16]. Meanwhile, there are different ways of dealing with the fuzzy deciding issues, for instance, Fuzzy AHP methodology [17], Fuzzy-TOPSIS methodology [18], and distinguished other researchers focus on alternative strategies and might be remarked to [18], [19] [10] and etc.

Generally, to model uncertainty in human preference, fuzzy sets might be incorporated with the pairwise comparison as an associate extension of AHP. Fuzzy AHP, comes into implementation to beat the counteractive approach and also the inability of the AHP in handling linguistic variables. The fuzzy AHP approach permits an additional correct description of the decision-making method. The fuzzy AHP tool may be viewed as a superior analytical methodology developed from the standard AHP. Therefore, it's not possible to mirror the choice makers' unsure preferences through crisp values. Therefore, fuzzy AHP is projected to alleviate the quality of the AHP methodology, wherever the fuzzy comparisons ratios are used [9]. For simplicity, the structure of fuzzy AHP phases is depicted in Fig. 2.

Because the triangular fuzzy number (TFN) is intuitive, straightforward to use, computationally easy, and helpful in promoting illustration and data process in a very fuzzy situation, it had been usefully applied to resolve FMCDM issues, within which the criteria values are implemented by the TFNs. Several methods are projected to resolve FMCDM with TFNs within the literature.

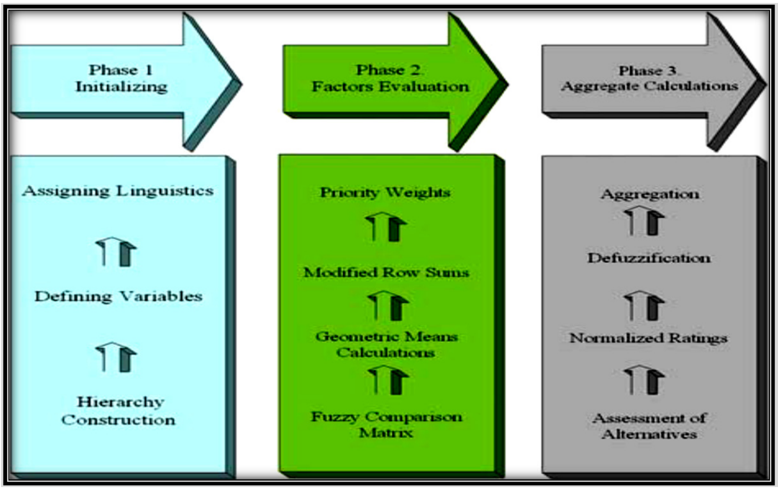

Fig. 2. The outline structure of fuzzy AHP.

The component as pointed out by Zhang and et.al. [21] models of the TFN, and the related formulas are given below with the assistance of Fig. 3. [22]. A triangular fuzzy number is represented as (l/m, m/u) or simply as (l, m, u). The parameters l, m and u respectively indicate the lowest possible value, the mode value and upper hopeful value that describe a fuzzy event. Each TFN has linear representations on its left and right aspect such its membership function may be outlined as:

$$\mu_{\widetilde{M}} = \begin{cases} 0, & X < 1 \\ (X-1)/(m-1), & 1 \le X \le m, \\ (u-X)/(u-m), & m \le X \le u, \\ 0, & X > u \end{cases}$$

A fuzzy number $\widetilde{M}$ will invariably incline by its corresponding left and right illustration of every degree of membership

$$\widetilde{M} = \left(M^{1(y)}, M^{r(y)}\right)$$

$$\widetilde{M} = (1 + (m-1)y, u + (m-u)y), y \in [0,1]$$

Where: l(y) and r(y) denotes the left side illustration and the right side illustration of a fuzzy number respectively.

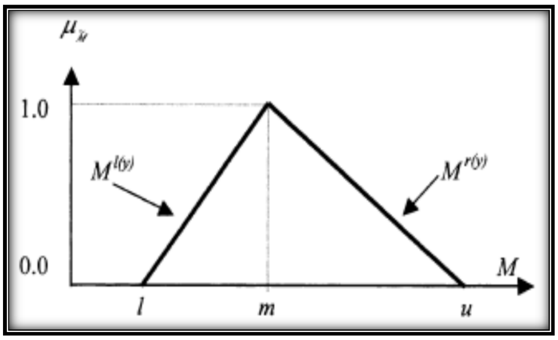

Fig. 3. Triangular fuzzy number representation.

4. Related Works

Because of the importance of selecting suppliers of product for certain applications, it has been the subject of great importance by researchers who uses FMCMD in different ways depending on the nature of the case. So the focus used in this vital area still addressing the fact that the majority research is concerning a particular case study of the qualitative aspect.

Çakır [24] Recognized robust supplier selection algorithm based on the hybrid use of a modified fuzzy AHP and generalized Choquet fuzzy integral (GCFI) methods at a steel company. The weights of the evaluation criteria were obtained from Fuzzy AHP and then GCFI was used to achieve the overall performance values of supplier alternatives. He also showed the robustness of the devised methodology through a sensitivity analysis. He concluded that the proposed integrated approach can effectively handle supplier selection and other MCDM problems especially when there are interdependent sub-criteria in a complex hierarchy of evaluation criteria.

Galankashi and et.al. [25] proposed an integrated new Balanced Scorecard–Fuzzy analytic hierarchical process (BSC–FAHP) model to pick out suppliers within the automobile industry. Information was gathered employing a literature survey and accredited using nominal group technique. Finally, a fuzzy AHP was used to select the best supplier. Also, within the same environment of an industrial automobile, Jain [26] was applied fuzzy AHP and TOPSIS for supplier selection as a tool for FMCDM approach. The selection process starts with identifying the criteria based on literature review and interviewing industry experts. Weights to criteria are assigned using AHP, and suppliers are ranked using AHP and TOPSIS. Consistency tests are carried out to check the quality of expert's inputs. Also, sensitivity analysis is done to check the robustness of the approach. The results address that fuzzy approaches could be effective and more accurate than the existing approaches for supplier selection problems.

Regarding to pair wise comparison scale based on triangular fuzzy numbers Chang [27] introduced a new approach of extent analysis method for synthetic extent value of the pair wise comparison. The first step in this method is to use TFNs for pair wise comparison by means of FAHP scale, while using synthetic extent values to obtain priority weights through fuzzy evaluation matrix of the criteria of different attributes relevant to the overall objective.

The trade-off between tangible and intangible factors which conflict with each other was the focus of Gurung & Phipon [28]. The purpose of their paper is to evaluate the suppliers in supply chain cycle using AHP and TOPSIS. Factors such as product quality, facility, delivery time and price have been taken into consideration while evaluating the suppliers in this supplier selection process. In the same sense of supply chain intuitionistic fuzzy TOPSIS method is proposed by Boran and et.al. [1] to select appropriate supplier in group decision making environment. Intuitionistic fuzzy weighted averaging operator is utilized to aggregate individual opinions of decision makers for rating the importance of criteria and alternatives which was illustrated by a numerical example.

Santis [29] presents a decision model based on the fuzzy AHP tool of maintenance supplier selection in a large Brazilian railway operator for evaluating 5 different suppliers. Eight criteria were adopted - technical capacity, financial status, relationship, operations management, security management, infrastructure, historic performance and costs.

Fuzzy AHP was used by Kahraman and et.al. [22] to compare the supplier firms. Choosing the best qualified supplier firm providing the foremost satisfaction for the factors determined. The purchasing managers were interviewed and therefore the most vital criteria taken under consideration by the managers were determined by a questionnaire. Researchers conclude a very important point in this area is that decisions are made today in more and more complex environments, choices are created nowadays a lot of in additional and more advanced environments, therefore the employment of experts opinions in numerous fields is critical, different criteria values of the systems are to be taken into consideration and consequently fuzzy multi criteria decision-making will overcome this problem.

Health care sector has also been included in the supplier selection process as Beşkese & Evecen [30] proposed a hierarchical structure model specific to the sector, and the criteria within the model were prioritized by considering the evaluations of the managers of 6 well-known healthcare organizations in Turkey.

Risk prioritization based on their threat level was the focus of López & Salmerón [31] by proposing a modernized AHP method. While Radionovs & Rebrovs [32] assumed risk factor as an element of lower level of the hierarchical structure and is expressed as a fuzzy number in FAHP, which is the combination of fuzzy evaluation of the probability of a corresponding adverse event and the fuzzy evaluation of potential losses related to the implementation of this event.

5. Problem Description

The main problem of this study is the decision support process to supply laboratory instruments to the university departments derived from supplier selection. The decision-making process for purchasing laboratory instruments considered an important and necessary process because it depends directly on the requirements restricted by certain qualitative parameters as well as on the supplier flexibility under restricted parameters and variables. Most of the purchasing of laboratory equipment based on personal relationships without relying on the efficiency and quality of the instrument. Additionally, there are many others obstacles facing decision-makers when selecting reliable and experienced suppliers at organizations such as universities that are a nonprofit organization under restricted budget and facing a different kind of risks. So that adopting Fuzzy AHP as a tool for solving the fuzzy multi-criteria decision-making problem is the axis of this study. Qualitative criteria should be determined by experts directly interacting with the core of the problem. Therefore, a specific methodology is required to reach the final objective decision of supplier selection based on almost risk-free in the form of qualified, reliable and effective laboratories equipment. Since the embedded risk is due to the failure of the process of selection right supplier, right required equipment, and reliable cost. Consequently, the qualitative side of the FAHP tool is one major issue of the problem.

6. Research Methodology

Fuzzy AHP is used to generate the weighting of the criteria perspectives and the weighting of the performance indicators. Fuzzy AHP is used to assist decision-making process based on the best and most suitable supplier selection objective. The objective in this specific problem are structured around three related criteria: supplier (SC), instruments (IC) and service performance (SP) grade that which considered in making selection decision of adequate and reliable supplier in order to satisfy restrictions carefully involved in the second level. Thereafter constructing the third level of the process contains sub-criteria for each one involved in the previous level. These sub-criteria includes (quality and safety SC1, information sharing SC2, flexibility and responsiveness SC3, social responsibility SC4, and experience SC5) which belong to the supplier criteria. While the instruments criteria can be classified into (disposable or reusable IC1, source IC2, cost IC3, use and maintenance IC4, quality assessment techniques IC5, and product reliability IC6); then finally the sub-criteria of service performance are (delivery lead time SP1, offers SP2, technical support SP3, value added SP4, and operating cost SP5). From these sub-criteria three alternative suppliers which are denoted as (local, internal and external and represented as S1, S2, and S3 respectively) for the purpose of this research are chosen.

The outline of the hierarchy structure of the adopted decision process of the Fuzzy AHP is illustrated in Fig. 5.

The key research approach involved in this work for adopting the Fuzzy AHP method is centered on the corresponding questionnaires developed and distributed to three different kinds of category experts. Firstly, senior scholar lecturers and adjunct research fellows from the field that are involved directly in using the lab equipment to assist the students to accept and understand the purpose of using the device and thus expand their understanding in the mode of interaction and development. Secondly, from purchasing managers and administrative officers who know the capabilities and restriction of expansion during periods of time and finally from financial affairs depending on five universities located in Baghdad province with a total number of 100 and the response was very adequate. While the concept of the degree of possibility for each criterion is used to reach the relative weights.

The qualitative aspect of the methodology is concentrated on the linguistic importance scale defined by the related experts. Accordingly triangular fuzzy scale is used for criteria selection beginning by fuzzy crisp values (1,1,1) for criterion has exactly the same importance (I). Then the scale start to vary from one criterion to another by step 0.5 and according to its significance of intersection between five observed scales which is ending by absolute importance (V) as shown in Table 1. and clarified by Fig. 4.

Table 1,
Linguistic importance scale.

Linguistic importance scale	Triangular fuzzy scale	Inverse of triangular fuzzy scale
Exactly the same (I)	(1,1,1)	(1,1,1)
Slightly important (II)	(1,1.5,2)	(0.5,0.67,1)
Serious importance (III)	(1.5,2,2.5)	(0.4,0.5,0.67)
More serious importance (IV)	(2,2.5,3)	(0.33,0.4,0.5)
Absolute importance (V)	(2.5,3,3.5)	(0.3,0.33,0.4)

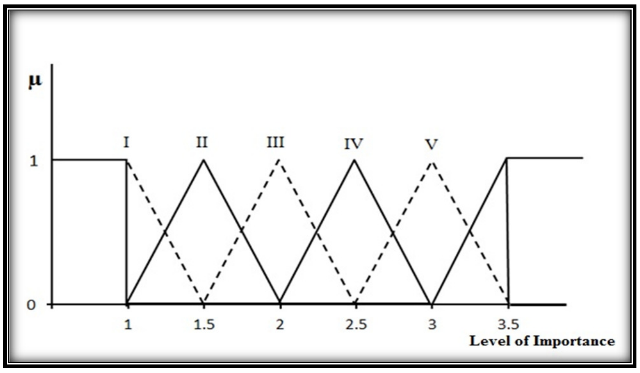

Fig. 4. Linguistic variables for the importance weight scale.

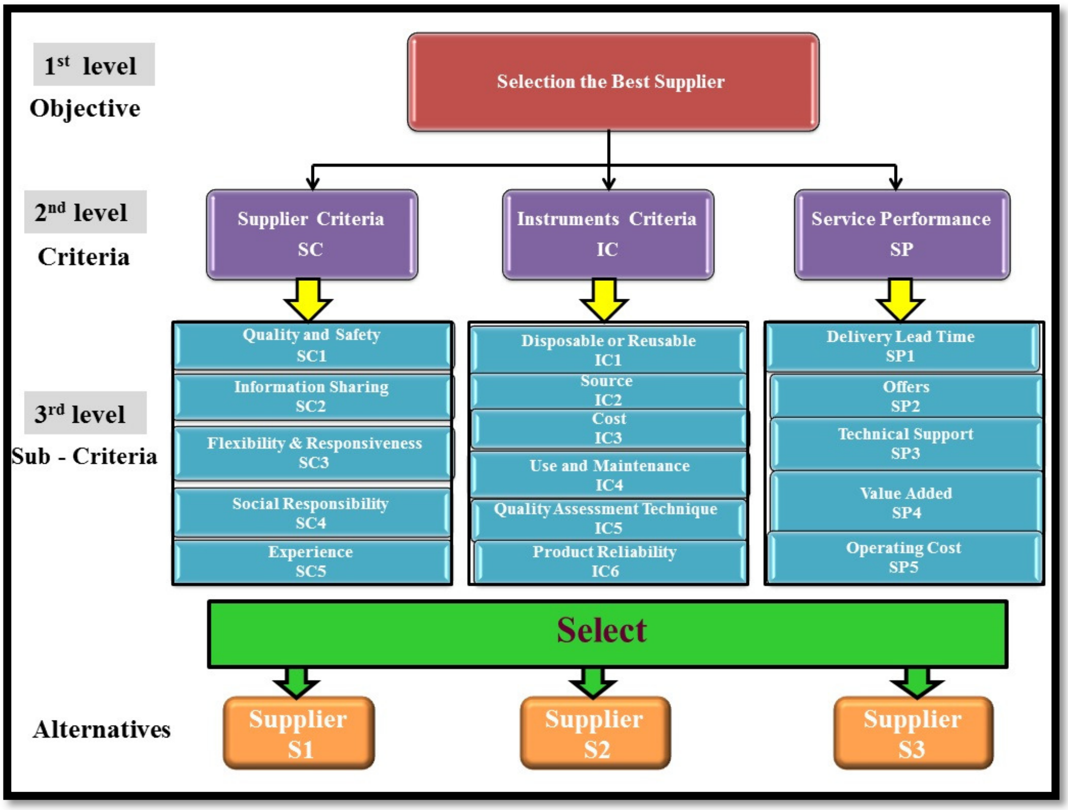

Fig. 5. Hierarchy structure for decision process of selecting best supplier.

A questionnaire was designed with Fuzzy AHP format (five-point scale and pairwise comparison) based on the hierarchy of Fig. 5. The questionnaires are to obtain the preference weights

among main-attributes, sub-attributes and alternatives. The main attributes determined by the pair wise questionnaire were given to the experts and requested to fill up by identity relative importance between the three decision criteria.

One hundred questionnaires are distributed to the three involved expert's categories. The number of valid questionnaires was 89 (89%). Thereafter, the responses collected from questionnaires are input to the Fuzzy AHP procedure explained later. All valid responses were collected and recorded. Hence, the data in Table 2. is based on an expert's opinion.

The structures of the adopted methodology for the multi-criteria decision-making process of supplier selection for lab critical instruments based on fuzzy AHP are summarized as in Fig. 6.

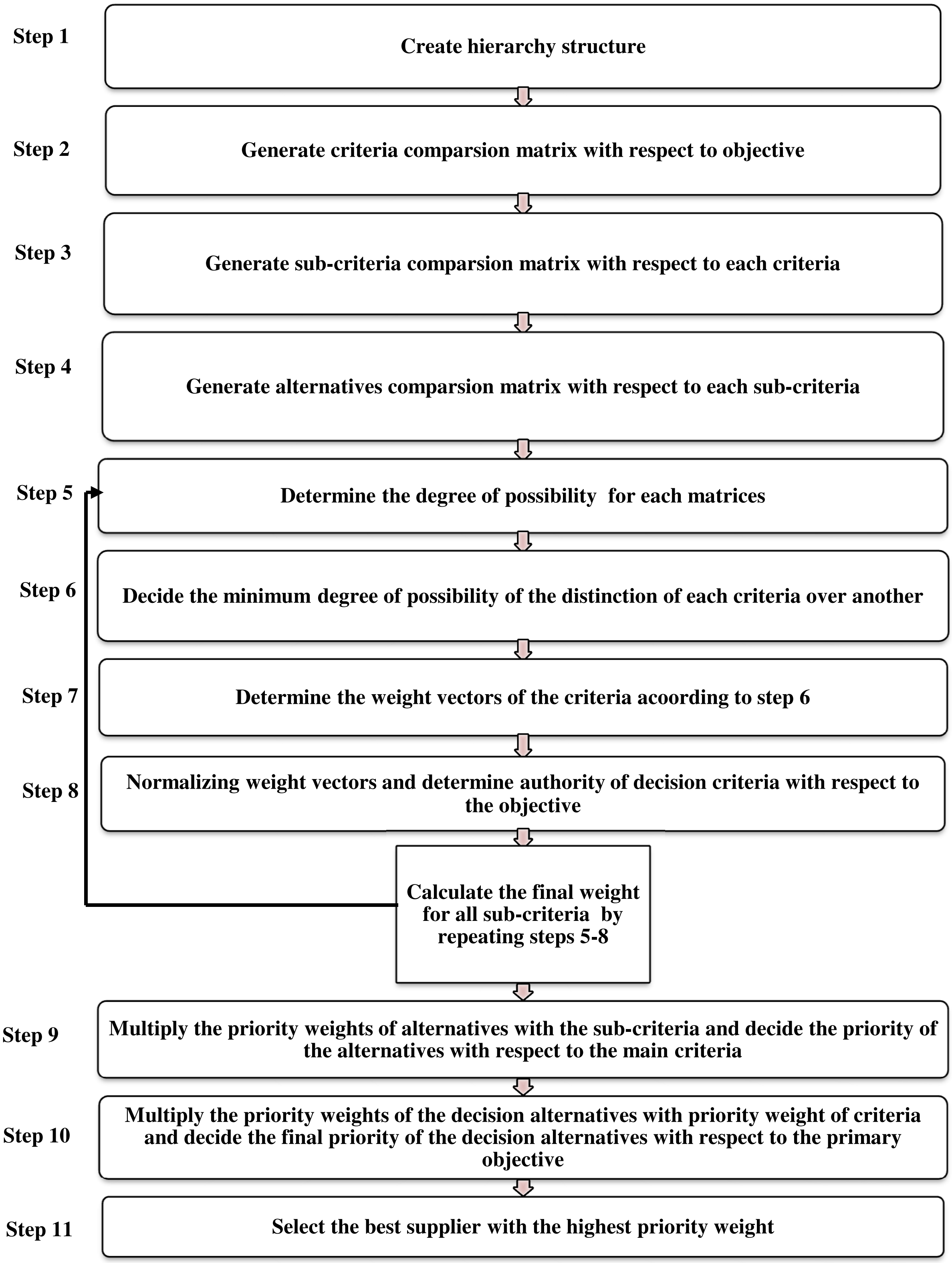

Fig. 6. Methodology of the Fuzzy AHP.

The procedure of using the mentioned methodology is given below with brief description of related steps (Chang, Applications of The Extent Analysis Method on Fuzzy AHP, 1996):

Step 1: create the hierarchy structure of the problem as clarified in Fig. 5.

Steps 2, 3 and 4: generate the fuzzy comparison matrix with respect to the objective, main criteria and sub-criteria depending on the opinion of the distinguished experts at five universities located at Baghdad as an instrument of study.

Step 5: Degree of possibility (Fi) for the fuzzy comparison matrix with respect to objective is calculated by multiplication of summation (lower, mode and upper value) horizontally by the summation (upper, mode and lower value) vertically, as clarified in equations below (Chang, Applications of The Extent Analysis Method on Fuzzy AHP, 1996):

Where:

i= 1,2,3 ……… n (no. of row).

j=1 ,2,3 ………..m (no. of column).

F_i = Degree of possibility which is used to compare between criteria.

$\sum_{j=1}^{m} a_T$ = summation (lower, mode and upper value) for each column of comparison matrix.

$[\sum_{i=1}^{n}\sum_{j=1}^{m} b_T]^{-1}$ = summation (lower, mode and upper value) for each row of comparison matrix; and can be called the inverse summation of data.

$$F_i = \sum_{j=1}^{m} a_T \times [\sum_{i=1}^{n}\sum_{j=1}^{m} b_T]^{-1} \quad \dots (1)$$

$$\sum_{j=1}^{m} a_T = [\sum_{j=1}^{m} a_{1j}, \sum_{j=1}^{m} a_{2j}, \sum_{j=1}^{m} a_{3j}] \quad \dots (2)$$

$$[\sum_{i=1}^{n}\sum_{j=1}^{m} b_T]^{-1} = [\frac{1}{\sum_{i=1}^{n} b_{1i}}, \frac{1}{\sum_{i=1}^{n} b_{2i}}, \frac{1}{\sum_{i}^{n} b_{3i}}] \quad \dots (3)$$

Step 6: the degree of possibility of criteria F_1 when comparing with other degree of possibility of criteria F_2; if it's greater than or equal, the degree of possibility equal 1, but if it's smaller than then we use **Eq. (4)** where (C) refer to the result of compare degree of possibility.

$$C = (F_2 \geq F_1) = \left[\frac{n_{11}-n_{23}}{(n_{22}-n_{23})-(n_{12}-n_{11})}\right] \quad \dots (4)$$

After that, we decide the minimum degree of possibility where refer to by symbol (P_i) to compare each results with other one as shown in Eq. (5)

$$P_i = \min C(F_1 \geq F_2, F_3 \dots\dots F_n) \quad \dots (5)$$

Step 7: weight vector of each criteria calculated by dividing the minimum degree of possibility by summation of the minimum degree of possibility.

$$w_i = \frac{Min\ P_i}{\sum_{i}^{n} Min\ P_i} \quad \dots (6)$$

Where: i= 1,2,3………n.

w= (*w1, w2, w3,* ……..n)

Step 8: normalizing the weight vector and decide the final weight for all sub- criteria.

Step (9) & Step (10): multiplying the priority weights of alternatives with the sub-criteria and decide the priority of the alternatives with respect to the main criteria. Furthermore multiplying the priority weights of the decision alternatives with priority weight of criteria and then decide the final priority of the decision alternatives with respect to the primary goal.

Step 11: select the highest priority weight as the best supplier.

7. Numerical Calculations for Supplier Selection

To clarify the steps of the methodology for laboratory apparatuses supplier selection process through sample of calculation that extracted from the related Tables (2 - 9). Microsoft Excel version 10 was used to make numerical calculations for this study, a snapshot as an example is shown in Fig. 7. As a starting point, we need to use Table 2. extracted from questioners data to illustrate the numerical calculations:

No. of rows i= 3, and No. of columns j=3 .

Using Eqs. (1, 2, and 3) in step 5 then:

F1 = (1.73, 1.9, 2.17) × (12.67, 10.57, 8.73) -1

= (21.9191, 20.083, 18.9441)

F2 = (3.5, 4.17, 5) × (12.67, 10.57, 8.73) -1

= (44.345, 44.0769, 43.65)

F3 = (3.5, 4.5, 5.5) × (12.67, 10.57, 8.73) -1

= (44.345, 47.565, 48.015)

The degrees of possibility of F1 over F2 & F3 are compared (step 6), if F1 ≥ F2, F3 the result equal 1 otherwise we used Eq. (4) as shown below:

$$C(F_1 \geq F_2) = \frac{44.354 - 18.9441}{(20.083-18.9441)-(44.0769-44.345)} = 18.05323$$

$C(F_1 \geq F_3) = 12.2055$

$C(F_2 \geq F_1) = 1$, $C(F_2 \geq F_3) = 1$

$C(F_3 \geq F_1) = 1$, $C(F_3 \geq F_2) = 1$

Then the minimum degree of possibility is found by comparing each result with other using Eq. (5)

$P_1 = \min C\ (18.05323, 12.2055) = 12.2055.$

Similarly, $P_2 = \min C(F_2 \geq F_1, F_3) = 1$

$P_3 = \min C(F_3 \geq F_1, F_2) = 1$

So that, the minimum is P = 1

Weight vector of main criteria (step 7) is approached by Eq. (6)

$w_1 = \frac{12}{14} = 0.857$, $w_2 = 0.071$, $w_3 = 0.072$

w = [0.857, 0.071, 0.072] T

The fuzzy comparison matrix with respect to overall objective with weight vector is given in Table 2. From Table 2 noticed the fuzzy comparison matrix with respect to overall objective which is debriefed from experts knowledge; after that we applied numerical calculations and normalizing a priority weights for each criteria.

Table 2,
Fuzzy comparison matrix with respect to overall objective.

O	SC	IC	SP	Weights
SC	(1,1,1)	(0.33,0.4,0.5)	(0.4,0.5,0.67)	0.857
IC	(2,2.5,3)	(1,1,1)	(0.5,0.67,1)	0.071
SP	(1.5,2,2.5)	(1,1.5,2)	(1,1,1)	0.072

Similarly; same steps are applied to calculate priority weights of fuzzy pair wise comparison matrix for sub-criteria of supplier (SC), instruments (IC) and service performance (SP) as revealed in Tables 3, 4, and 5 respectively

Table 3,
Fuzzy comparison matrix of supplier criteria.

SC	SC1	SC2	SC3	SC4	SC5	Weights
SC1	(1,1,1)	(0.5,0.67,1)	(0.33,0.4,0.5)	(0.4,0.5,0.67)	(0.5,0.67,1)	0.132
SC2	(1,1.5,2)	(1,1,1)	(0.4,0.5,0.67)	(0.5,0.67,1)	(0.3,0.33,0.4)	0.242
SC3	(2,2.5,3)	(1.5,2,2.5)	(1,1,1)	(0.3,0.33,0.4)	(0.4,0.5,0.67)	0.142
SC4	(1.5,2,2.5)	(1,1.5,2)	(2.5,3,3.5)	(1,1,1)	(0.5,0.67,1)	0.252
SC5	(1,1.5,2)	(2.5,3,3.5)	(1.5,2,2.5)	(1,1.5,2)	(1,1,1)	0.232

Table 4,
Fuzzy comparison matrix of instruments criteria.

IC	IC1	IC2	IC3	IC4	IC5	IC6	Weights
IC1	(1,1,1)	(0.4,0.5,0.67)	(0.5,0.67,1)	(0.4,0.5,0.67)	(0.3,0.33,0.4)	(0.33,0.4,0.5)	0.163
IC2	(1.5,2,2.5)	(1,1,1)	(0.33,0.4,0.5)	(0.3,0.33,0.4)	(0.4,0.5,0.67)	(0.3,0.33,0.4)	0.157
IC3	(1,1.5,2)	(2,2.5,3)	(1,1,1)	(0.5,0.67,1)	(0.33,0.4,0.5)	(0.5,0.67,1)	0.145
IC4	(1.5,2,2.5)	(2.5,3,3.5)	(1,1.5,2)	(1,1,1)	(0.33,0.4,0.5)	(0.4,0.5,0.67)	0.194
IC5	(2.5,3,3.5)	(1.5,2,2.5)	(2,2.5,3)	(2,2.5,3)	(1,1,1)	(0.5,0.67,1)	0.168
IC6	(2,2.5,3)	(2.5,3,3.5)	(1,1.5,2)	(1.5,2,2.5)	(1,1.5,2)	(1,1,1)	0.173

Table 5,
Fuzzy comparison matrix of service performance criteria.

SP	SP1	SP2	SP3	SP4	SP5	Weights
SP1	(1,1,1)	(0.33,0.4,0.5)	(0.3,0.33,0.4)	(0.4,0.5,0.67)	(0.3,0.33,0.4)	0.216
SP2	(2,2.5,3)	(1,1,1)	(0.5,0.67,1)	(0.33,0.4,0.5)	(0.4,0.5,0.67)	0.167
SP3	(2.5,3,3.5)	(1,1.5,2)	(1,1,1)	(0.4,0.5,0.67)	(0.3,0.33,0.4)	0.235
SP4	(1.5,2,2.5)	(2,2.5,3)	(1.5,2,2.5)	(1,1,1)	(0.33,0.4,0.5)	0.186
SP5	(2.5,3,3.5)	(1.5,2,2.5)	(2.5,3,3.5)	(2,2.5,3)	(1,1,1)	0.196

In the same way, calculation weights vector repeated 16 times for fuzzy pair wise comparison matrixes of alternatives with respect to five sub-criteria of supplier (SC), six sub-criteria of instruments (IC), and five sub-criteria of service performance (SP) based on Fig. 4 and as given by Tables 6, 7, and 8 respectively.

Table 6,
Summary of priority weights for sub-criteria of supplier.

	SC1	SC2	SC3	SC4	SC5	Alternative Priority Weights
Weights	0.132	0.242	0.142	0.252	0.232	
Alternatives						
S1	0.802	0.509	0.771	0.731	0.787	0.705
S2	0.096	0.258	0.121	0.138	0.181	0.169
S3	0.102	0.233	0.108	0.131	0.032	0.125

Table 7,
Summary of priority weights for sub-criteria with instruments.

	IC1	IC2	IC3	IC4	IC5	IC6	Alternative Priority Weights
Weights	0.163	0.157	0.145	0.194	0.168	0.173	
Alternatives							
S1	0.354	0.588	0.853	0.797	0.116	0.751	0.577
S2	0.132	0.198	0.121	0.181	0.099	0.236	0.162
S3	0.514	0.214	0.026	0.022	0.785	0.013	0.259

Table 8,
Summary of priority weights for service performance sub-criteria with suppliers.

	SP1	SP2	SP3	SP4	SP5	Alternative Priority Weights
Weights	0.216	0.167	0.235	0.186	0.196	
Alternatives						
S1	0.51	0.623	0.511	0.309	0.594	0.508
S2	0.34	0.243	0.371	0.235	0.282	0.300
S3	0.15	0.134	0.118	0.456	0.124	0.191

Thereafter, the final decision can be reached through developing priority weights of the three main criteria (SC, IC, and SP) with the three alternative (S1, S2 and S3) to reach the overall objective as mentioned in Table 9 which shows that suppler S1 (local supplier) is the best decision to be selected.

Table 9,
Summary combination of priority weights: Main criteria of the overall objective.

	SC	IC	SP	Alternative Priority Weights
Weights	0.857	0.071	0.072	
Alternatives				
S1	0.705	0.577	0.508	0.682
S2	0.169	0.162	0.300	0.178
S3	0.125	0.259	0.191	0.139

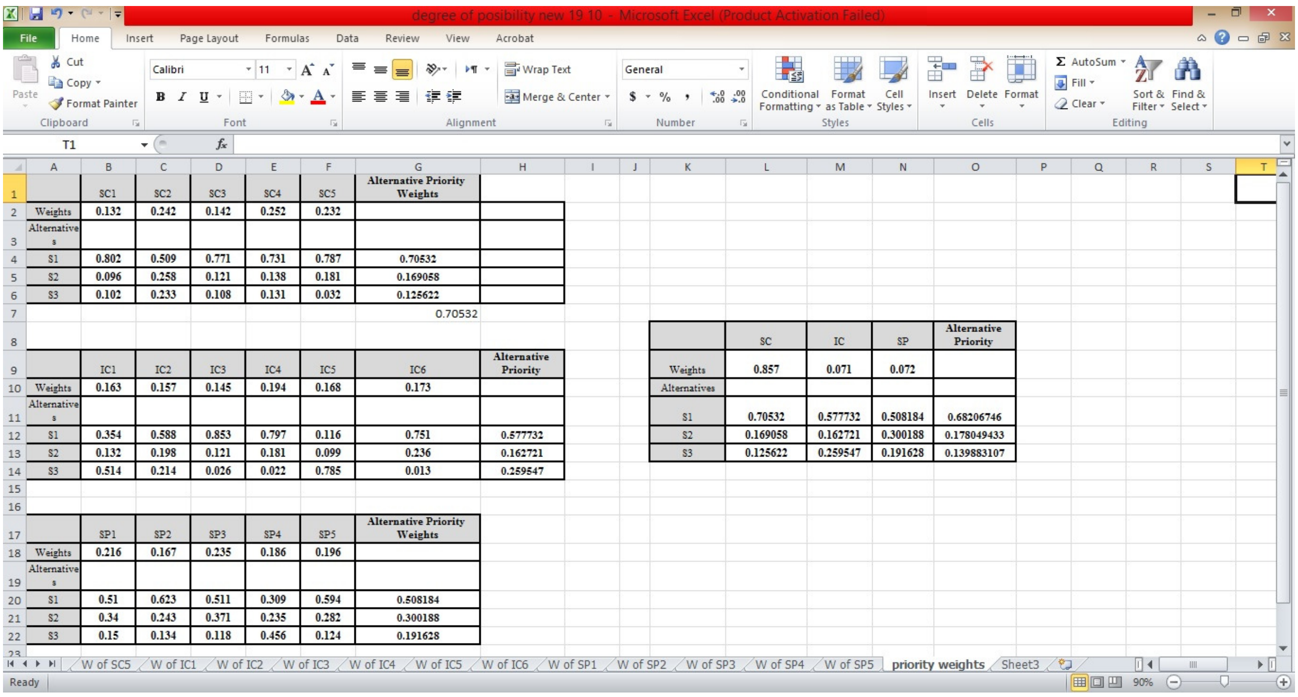

Fig. 7. Snapshot of Calculations in Excel window.

8. Results and Discussion

The decision-making process pertaining to purchasing laboratory instruments from different suppliers for education purpose at the university level is considered an important and necessary process because it depends directly on the requirements restricted by certain qualitative and quantitative parameters. Most of the purchasing of laboratory equipment based on personal relationships without relying on the efficiency and quality of the instrument. There are many obstacles facing decision-makers at universities when selecting reliable and experienced suppliers, as universities are nonprofit organizations under limited budget and facing a different kind of risks.

The decision of selecting the supplier is a risky complicated process and is considered as a multi criteria decision process having a various priority weights extracted from expert's opinions used to finalize the decision objective.

One of the methods used to solve such problems are FAHP outcome represented in Table 9. Indicates that supplier (S1) who is the local supplier has a large priority weight (0.682) which means the most suitable supplier according to the qualitative aspects of reliable experts in the field. Three main criteria were the focus of the study. These are supplier, instruments and service performance criteria. Each is divided into sub criteria with a total of sixteen. The pairwise comparisons with five scales linguistic values are used. Each of them is reflected by three fuzzy values (min, mode, high). The step from one value to the next is at 0.5 intervals. Fuzzy AHP methodology is built with different steps to be ended with the decision of the most suitable supplier selected.

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عملية التحليل الهرمي المضبب للحد من المخاطر المضمنة في اختيار قرار التخطيط الصحيح

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الخلاصة

الهدف من هذا البحث هو توفير تقنية اختيار فعالة كجزء من عملية التخطيط لتوجيه صانعي القرار لتحديد تفضيلات مورد على آخر لشراء ألادوات المختبرية المستخدمة في مجال التعليم. استخدمت عملية التحليل الهرمي المضبب كعملية اتخاذ قرار متعدد المعايير كاداة في مجال الهندسة الصناعية مع التركيز بشكل خاص على الجوانب النوعية المطلوبة لصانعي القرار. في حين يتم استخدام مفهوم درجة الإمكانية لكل معيار للوصول إلى أوزانها النسبية. منهجية محددة تم إنشاؤها للوصول إلى القرار النهائي الموضوعي لاختيار الموردين. تم إعداد استمارة استبيان وتوزيع مائة نسخة على خمس جامعات في محافظة بغداد. وكانت الاستجابة مقبولة. تم تبني ثلاثة معايير رئيسية - المورد (SC) والأدوات (IC) وأداء الخدمة (SP). علاوة على ذلك، هناك ستة عشر معيارًا ثانويًا لتقييم ثلاثة موردين محتملين. ان القرار النهائي الذي تم التوصل اليه هو خالي من المخاطر تقريبا بالاعتماد على الجوانب النوعية التي اعتمدت من قبل الخبراء. وان المجهز المحلي حصل على وزن اسبقية عالي باستخدام برنامج الاكسيل لاجراء الحسابات المتسلسلة في عملية التحليل الهرمي المضبب.