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Research Article

Application of Fuzzy Analytical Hierarchy Process and Quality Function Deployment Techniques for Supplier's Assessment

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Abstract

Vendor Selection Problem (VSP) has been considered in this paper as an integrated method of Fuzzy Analytic Hierarchy Process (FAHP) and Quality Function Deployment (QFD) in the hygienic company. In QFD method, determining the importance of the "weights" for the customer requirements is an essential and crucial issue. FAHP has been used to determine the importance of the "weights" for Product Designing which incorporates 5 important criteria in a hygienic company namely Cost, Sustainability, Delivery Time, Creativity and Quality in 4 categories such as Commercial, Technical, Strategic, Green needs with 12 sub-attributes. The new approach can improve the imprecise ranking of customer requirements and provides a decision tool that facilitates the vendor assessment and selection. The most significant advantage of this integrated method is using of it as a self-evaluation tool in the organization to determine weaknesses and strengths, so it can help researchers to solve this specific subject for supplier’s selection.

***Keywords**:* QFD; AHP; Supplier Assessment; Fuzzy Conditions.

1. Introduction

The selection of suppliers becomes more complex when groups and organizations participate in this process and the attribute of each group had different suppliers. A decision-making team can include staff, experts and managers from various departments (such as research and development, engineering, quality assurance and commercial).As for the multiplicity of different suppliers in today's competitive industrial world, choosing a suitable supplier is fundamentally importance. Today's highly competitive markets have forced companies to respond quickly and accurately to customer needs, to meet customer satisfaction, to improve and develop their market position. These pressures encourage companies to use effective tools. In such circumstances, the role of suppliers and their management of the chain are fatally important since a wrong decision can lead the company to higher costs and, consequently, to a considerable damage to the relationship of the supply chain. In order to obtain an acceptable profit, it is necessary selection of suitable suppliers as a multi-attribute problem with qualitative and quantitative factors that must be solved.

In this condition the selection and evaluation process of the suppliers of each group can be declared as an independent characteristic of different suppliers.

Finally, it is necessary to manage the choice of a suitable supplier and meets the quantities that required by each selected supplier.In addition, these goals will increase customer satisfaction levels resulting in better profits if the mentioned goals and management principles are achieved.

The multi-attribute decision making approach has been shown to be better than considering just a single attribute.Faris,C.,Robinson,P& Wind,Y.(2015)considered a traditional method without covering all aspects of a general and universal supplier selection problem. But in multi-attribute decision-making methods, other attribute are also taken into consideration (Cost, Quality, Flexibility, Delivery, etc.). One of the issues under evaluation for the supplier selection attribute is that these criteria can be quantitative or qualitative amounts. DeBoer, L.,Labro,E& Morlacchi,P.(2012).

In their research, the linguistic judgment on the client's requirements is converted into triangular fuzzy numbers. These triangular fuzzy numbers are used to build a pairwise comparison matrix for the Analytical Hierarchy Process (AHP).By applying Fuzzy AHP with extension analysis in Muralidharan, C.,Anantharaman,N& Deshmukh,S.(2011).weights of importance can be obtained. The aim of this study is to propose and demonstrate a decision-making model for the selection of suppliers based on Fuzzy AHP and implementation of Quality Functions Deployment (QFD). This research organized into 6 sections. In section 1, the most important attribute are obtained from the buyer's expert team. Section 2 develops some topics considered strategic factors in the selection of the supplier. Section 3 discusses materials and methods. In section 4, the combination of the Fuzzy AHP and QFD methodology is discussed with a case study from a hygienic industry, which is used to demonstrate the application of the proposed method. Finally, the results of the Fuzzy AHP and QFD methodology and conclusions and discussion are presented in sections 5 and 6.

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2. Literature Review

By examining the multi-attribute supplier assessment and selection approaches through recent literature reviews and journal articles, three key issues are identified: 1) which approaches are generally affected? 2) To which evaluation attribute is more attention paid? And 3) there is some insufficiency in supplier selection approaches.

Karpak, B.,Kumcu,E&Kasuganti,R.(2012). Created a Goal Programming (GP) model to evaluate and select suppliers. Three objectives were considered in their model, including cost, quality and reliability of delivery. The GP model has been extended to determine the optimal quantity of products ordered.Narasimhan,R., Talluri,S & Mendez,D.(2014). Built a multi-objective programming model to choose the optimal suppliers and determined the optimal order quantity. Five attribute have been proposed to evaluate supplier performance. The authors suggested that the Analytical Hierarchy Process (AHP) could be one of the possible ways of generating weightings. Akarte,M., Surendra,N & Ravi,B .(2010) establish a web-based system for AHP to evaluate management service providers based on 18 attribute. In their system, suppliers had to register and then enter their merger specifications. To evaluate suppliers, buyers had to determine the importance weightings for the attribute based on the merger specifications, then assign the performance evaluation for each criterion using a torque wise comparison.

Muralidharan,C.,Anantharaman,N&Deshmukh,S.(2011).proposed a five-phase AHP-based model to support decision-makers in the evaluation and selection of suppliers in compliance with nine evaluation attribute. People from different sectors of company, such as purchasing, production and quality control, were involved in the selection process.

Alinezhad,A., Amini.M.(2011). Expressed contemporary offer is to maintain a long-term partnership with suppliers and to use a smaller but reliable number of suppliers. Therefore, choosing the right suppliers not only involves scanning a series of price lists, but also selecting suppliers depends on a wide range of factors which include both quantitative and qualitative attributes.

Chen,C., Wang,S.(2009).developed an interactive AHP model to facilitate supplier selection for decision makers. The model implemented to determine the relative importance of evaluating attribute without subjective human judgment interference has incorporated a method called the interaction chain. The AHP was applied only to generate the overall score for alternative suppliers based on relative importance levels. Chan, F., Kumar, N., & Tiwariz,M.(2007). Used AHP to evaluate and select the best suppliers. The AHP is composed of six evaluation attribute and 20 sub-factors, in which the relative importance scores have been calculated according to the customer's needs.

Liu,F., Hai,H.(2005). Used AHP to evaluate and select suppliers, similarly to Chan,F.(2003). The authors did not use the comparison in pairs of AHP to resolve the assessments of relative importance between the attribute and sub-factors. Instead, the authors applied the classification method, which allowed all managers to establish the order of the attribute rather than the weights. Chan,F., Chan,H.(2004). Developed an AHP-based decision-making approach to solve the supplier selection problem. Potential suppliers were assessed on the basis of 14 attribute. A compassion analysis was performed using Expert Choice Software to examine the response of alternatives when the classification of the relative importance of each criterion was changed.

Hou,J., Ejb,D & Mvc,S.(2007). Developed an AHP-based decision support system for the supplier selection problem in a mass customization environment. Factors were considered by external and internal influences to meet the needs of markets in the changing global environment.

Talluri,S., Baker,R.(2013). Used a three-phase approach for the design of the logistic distribution network. Potential stakeholders, including suppliers, manufacturers and distributors, were assessed individually that in Phase I applied the Data Envelope Analysis (DEA). The authors used six evaluation factors proposed by other researchers for supplier evaluation, in which it includes two inputs and four outputs. On the basis of the presentation scores obtained in phase I and the optimal number of interested parties to be used in phase II, the optimal paths of material from selected suppliers to producers for further deposits were identified.

Chen,C., Huang,S.(2015). Presented a hierarchical model based on fuzzy set theory to address the supplier selection problem. The linguistic values were used to evaluate the classifications and weights for supplier evaluation factors. These linguistic classifications could be expressed in triangular or fuzzy trapezoidal numbers. The proposed model was able to deal with both quantitative and qualitative attribute. Alinezhad, A.,Makui,A & Kianimavi.,R.(2007). Applied a fuzzy AHP to select the best supplier in a turkish manufacturing company. Decision makers could specify preferences regarding the importance of each evaluation criterion using the linguistic variable. Alinezhad, A., Esfandiari,N. (2012). Used a fuzzy AHP for supplier selection as in the case of in this approach, the triangular fuzzy numbers and the fuzzy synthetic extension analysis method have been demonstrated to represent the comparative judgment of decision makers and to decide the final priority of several attribute. Faris,C.,Robinson &Wind,Y.(2015). Formulated a mixed integer nonlinear programming model to solve the multi-attribute supply problem. The model has been extended to determine the optimal allocation of products to suppliers in order to minimize the total annual purchase cost. Three restrictions were considered in their model.

Alinezhad,A., Khalili,J.(2019).applied Quality Functions Deployment (QFD) and the Analytical Network Process (ANP) to analyze environmental production requirements in linguistic preferences. And so a model of Environmental Production Requirements (EPR) and attributes of Sustainable Production Indicators (SPI) were used. The conclusion of five aspects of the EPR and twenty-two feasible ISP attribute are indicated. Chan,C., and Kumar,D.(2010).Suggested global supplier development by considering risk factors and using an extended AHP-based fuzzy approach. They indicated risk factors in their supplier selection model. Fuzzy Extended Analytical Hierarchy Process (Fuzzy-EAHP) has been applied to address this problem. Costs, quality, service performance and supplier profile with risk factors were considered in their model.

Bevilacqua,M., Ciarapica,F & Giacchetta,G.(2010). Presented the fuzzy-QFD approach to supplier selection. They got the “What’s “from the company's requirements after the “How’s” was found from the vendor evaluation attribute. They used a fuzzy algorithm to make a final decision making based on the Fuzzy Suitability Index (FSI).

3. Background

3.1. Quality Function Deployment (QFD)

QFD is a tool for translating customer needs into technical product requirements for new products and services that developed by Akao in the late 1960s and early 1970s.Chan, L., Wu,M.(2015).The main concept of traditional QFD took into account four relationship matrices that included product planning, part planning, process planning and production planning matrices, respectively Mirmozaffari,M.P .,Alinezhad,A.(2017).Each translation used a matrix, also called a House of Quality (HOQ), as shown in Figure 1. First, the product planning matrix is established. Customer requirements must be translated into the second matrix as input for the development of product design requirements. Second, in the parts planning matrix, important design requirements are related to the distribution of the characteristics of the parts components. In addition, the characteristics of the component parts are also related to the production operations. In the production planning matrix, process parameters and control limits are determined in the same way. Dikmen,M., Birgonul,T .(2005). Fuzzy set theory has shown advantages in vague, inaccurate and uncertain contexts and recalls human reasoning in its use of rough information and uncertainty to generate decisions. It has been specially designed to mathematically represent uncertainty and vagueness and provide formalized tools to deal with the inherent inaccuracy of many decision problems. Kahraman,C., Cebeci,U & Ulukan,Z.(2010). The fuzzy set theory implements classes and grouping of data with boundaries that are not clearly defined (i.e. fuzzy). Fuzzy set theory includes fuzzy logic, fuzzy arithmetic, fuzzy mathematical programming, fuzzy graph theory and fuzzy data analysis, usually the term fuzzy logic is used to describe this. Fuzzy-AHP is the fuzzy extension of Analytic Hierarchy Process (AHP) to efficiently manage the confusion of data involved in the decision of the best global supplier.

The Analytical Hierarchy Process (AHP) has been widely used to address multi-attribute decision problems. However, it has generally been criticized for using a discrete scale of one to five which can handle uncertainty and ambiguity. Saaty,T.(1980).The relative importance of different decision attribute in the global selection of suppliers implies a high degree of subjective judgment and individual preferences.

The hierarchy of decision variables is the subject of a pairwise comparison of the Analytical Hierarchy Process (AHP). In the conventional process of analytical hierarchy, pairwise comparison is established, using a nine-point scale that converts human preferences among the alternatives available as equally, moderately, strongly, very strongly or extremely preferred. Cheung,O., Lam,T & Leung,M .(2011).Although the discrete scale of the Analytical Hierarchy Process (AHP) has the advantages of simplicity and ease of use, it is not enough to take into account the uncertainty associated with mapping one's perception on a number. The linguistic evaluation of human opinion and judgments is vague and it is not logical to represent it in terms of exact numbers. It is more suitable to make judgments at intervals than fixed-value judgments.

Hence, triangular fuzzy numbers are used to decide the priority of one decision variable over another. The synthetic extension analysis method is used to decide the final priority weights based on triangular fuzzy numbers and so-called as extended Fuzzy AHP Alinezhad, A., Esfandiari,N. (2012). It is easier to understand and can effectively manage both qualitative and quantitative data in decision problems with multiple attributes. In this approach, triangular fuzzy numbers are used for the preferences of one criterion over another and then using the extension analysis method, the value of the synthetic extension of the pairwise comparison is calculated. Based on this approach, weight vectors are decided and normalized, then normalized weight vectors will be determined. As a result, the final priority weights of the alternative global suppliers are decided based on the

Different weights of attributes. The highest priority would be given to the supplier with the highest weight Oboulhas,K.(2009).

3.2. Fuzzy Sets

Fuzzy set theory was defined by Zadeh,L.(1965). To deal with problems in the way a source of vagueness is involved. A fuzzy set can be introduced mathematically by assigning a value to every possible individual in the universe of discourse in which each value representing its degree of belonging to the fuzzy set.

Fuzzy set theory mathematically indicates and manages unclear or inaccurate judgments. The fuzzy set theory is designed to express the extraction of the primary possible result from a multiplicity of information that can be vague and inaccurate. Fuzzy set theory treats vague data as distributions of possibilities in terms of set memberships.

Once determined and defined, the membership sets can be effectively used in logical reasoning. Triangular fuzzy numbers are one of the main components. According to the definition of Plaarhoven,J., Pedrycz,W.(2016). A Triangular Fuzzy Number (TFN) should have some basic characteristics as described in the next section.

3.3. Triangular Fuzzy Numbers(TFN)

A fuzzy number is a special fuzzy set. The following expressions are, $F = \{(x, \mu_F(x)), x \in R\}$ $R_1 = -\infty \prec x \prec +\infty$ and $\mu_F(x)$ which the last one is called membership function and possesses a continuous mapping from R_1 to the close interval of [0,1]. A triangular fuzzy number can be denoted as M = (l, m, and u). The main operational laws for two triangular fuzzy numbers M_1 and M_2 are as follows Kaufmann,A., Gupta,M.(2010).

$$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (1)$$

$$M_1 * M_2 = (l_1 * l_2, m_1 * m_2, u_1 * u_2) \quad (2)$$

$$M_1^{-1} = \left[\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right], M_2^{-1} = \left[\frac{1}{u_2}, \frac{1}{m_2}, \frac{1}{l_2}\right] \quad (3)$$

To calculate the aspects and evaluation attribute, the measures are manifold and often structured in a study framework, with qualitative evaluation. Numerous aspects and attribute must be taken into consideration when structuring the hierarchical structure. This proposed hierarchy allows experts to identify options using linguistic expressions.

To effectively solve study problems with a hierarchical structure, this research uses a series of fuzzy numbers in a simple method. The triangular fuzzy membership function (Table1) can accommodate qualitative data while evaluators process the evaluation in linguistic information. The following sections represent the application method for this study.

4. Numerical Example

4.1. Hygienic Industry

The development of medicine refers to all activities after a compound has been recognized as a potential medicine to find its suitability as a medicine. The goals of medicine development are to determine the appropriate formulation and concentration, as well as to establish safety. The amount of capital required for the development of discovered medicines has made it a historic strength of large hygienic companies.

The hygienic industry develops and manufactures medicines authorized for use as drugs. Hygienic companies offer medicines that treat many of the world's most serious and widespread diseases. Hygienic companies can also deal with branded and generic medicines. They must consider a number of laws and regulations regarding patents, tests and marketing of drugs.

The discovery of medicine is the process in which potential medicines are discovered or designed. In the past, most medicines have been discovered by separating and extracting the effective ingredient from traditional drugs.

4.2. Customer Requirements (What's)

There are generally three basic characteristics required for products or services purchased from external suppliers by the hygienic company considered in this study:

(1)Strategic requirements, in terms of organization culture and strategy, sector situation and reputation, performance history, supplier information system and transportation.

(2)Commercial requirements, in terms of financial capacity, financial offer, discount and quantity discount.

(3)Technical requirements, in terms of technical information, technical service, research and development capacity and supplier certificate.

In reality, the properties considered essential for a product or service purchased outside the company will vary from case to case; sometimes, for example, after-sales service may be of little interest, since this is often governed by separate contracts, but the list above still contains the significant attributes sought in most purchases.

4.3. Engineering Characteristics(How's)

In a comparative session, our group of ten experts were presented with various attribute that emerged from a careful review of the literature on the selection of suppliers and with the considerable purchasing experience for Pharmacy Company. This analysis identified four crucial attribute for evaluating suppliers in our specific case. The following attribute (How's) were considered:

(1) Quality
(2) Delivery Time
(3) Sustainability
(4) Cost
(5)Creativity

4.4. Weighting for Hierarchy of the Customer Requirements

The extension analysis method and the principles for comparing fuzzy numbers are used to obtain estimates for weight vectors for the individual levels of a hierarchy of customer needs.Chang,D.(2010). The extension analysis method is used to consider the extent of an object to be satisfied for the goal, that is, the extent satisfied. In the method, the "extension" is quantified using a fuzzy number. Based on the fuzzy values for analyzing the extent of each object, it is possible to obtain a synthetic fuzzy grade value, which is defined as follows. if $\underline{X} = \{x_1, x_2, \ldots, x_n\}$ taken as a set of objects and $\underline{U} = \{u_1, u_2, \ldots, u_m\}$ assumed as a goal set, so based on the extension analysis method, each object could be used to perform the extension analysis for each goal respectively. Therefore, the analysis values of extension M for each object could be obtained as follows:

$M^1_{gi}, M^2_{gi}, \ldots, M^m_{gi}$, $(i = 1, 2, \ldots, m)$.

Where all the M^j_{gi} $(j=1,2\ldots,n)$ are triangular fuzzy numbers. Therefore, the value of fuzzy synthetic degree with respect to the i^{th} $(i = 1, 2, \ldots, m)$. Object is defined as Esfandiari, N. (2013):

$$S_k = \sum_{j=1}^{n} M_{kj} \otimes \left[\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij} \right]^{-1} \quad (4)$$

Based on the above definition, the fuzzy synthetic degree values of all elements in the k^{th} level can be calculated using equation (4) based on the fuzzy judgment matrix of the k^{th} level;

$$S_I^{\ K} = \sum_{j=1}^{n} a_{ij}^{\ k} \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij}^{\ k} \right)^{-1} \quad (5)$$

Where, $S_I^{\ K} j$ is the fuzzy synthetic degree values of element i is the k^{th} level and $A^k = (a_{ij})^k_{nn}$ is the fuzzy judgment matrix of the k^{th} level. j=1, 2,…, n, i = 1, 2, . . . , m.

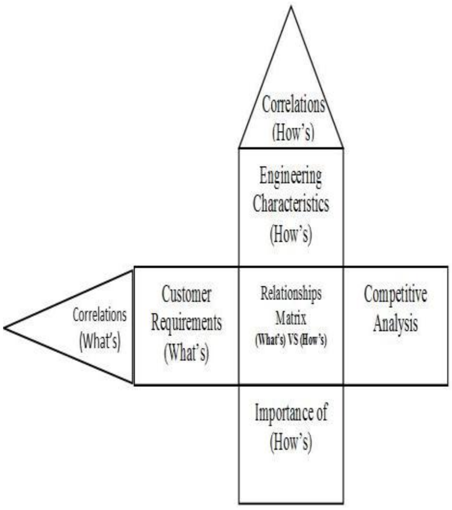


Fig.1. House of Quality (HOQ).

4.5. Judgment Matrixes for FAHP

The hierarchy of attributes (customer requirements) is the subject of a pair wise comparison of the Analytical Hierarchy Process (AHP). After building a hierarchy, decision makers are asked to compare the elements at a given level on a pair wise basis in order to estimate their relative importance in relation to the element at the immediately preceding level. In the conventional Analytic Hierarchy Process (AHP), the comparison between the pairs is carried out using a ratio scale. A five-point scale is commonly used to show participant's judgments or preferences among options as equally, moderately, strongly, poor or very poor. Although the discrete scale of one to five has the advantages of simplicity and ease of use, it does not take into account the associative uncertainty with the mapping of one's perception (or judgment) on a number. However, it is also known that human assessment of the relative importance of individual customer needs is always subjective and vague. The linguistic terms that people use to express their feelings or judgments are unclear. The use of objective, defined and precise numbers to represent linguistic assessments is not very reasonable, although widely adopted. Mirmozaffari,M.P .,Alinezhad,A.(2017).The fuzzy set theory supported for the first time in 1965, Zimmermann,H.(1996). And it has become an important theory for dealing with ambiguity in a system.

In this article, the widely adopted triangular fuzzy number technique in a hygienic company, customers' requirements have been divided into **4** groups, Technical, Commercial, Strategic and Green Requirements for which they also have sub-attributes.

Technical Requirements have been divided into **3** sub-attributes which are Technical Information, Technical Services, and Supplier Certification.

Commercial Requirements are divided into**3** sub-attributes which are Financial Capacity, Cash Discount and Quantity Discount.

Strategic Requirements are divided into **3**sub-attributes which are Organization's Culture, Performance History and Transportation.

Green Requirements are divided into**3** sub-attributes which are Green Procurement, Green Distribution and Green Logistics.

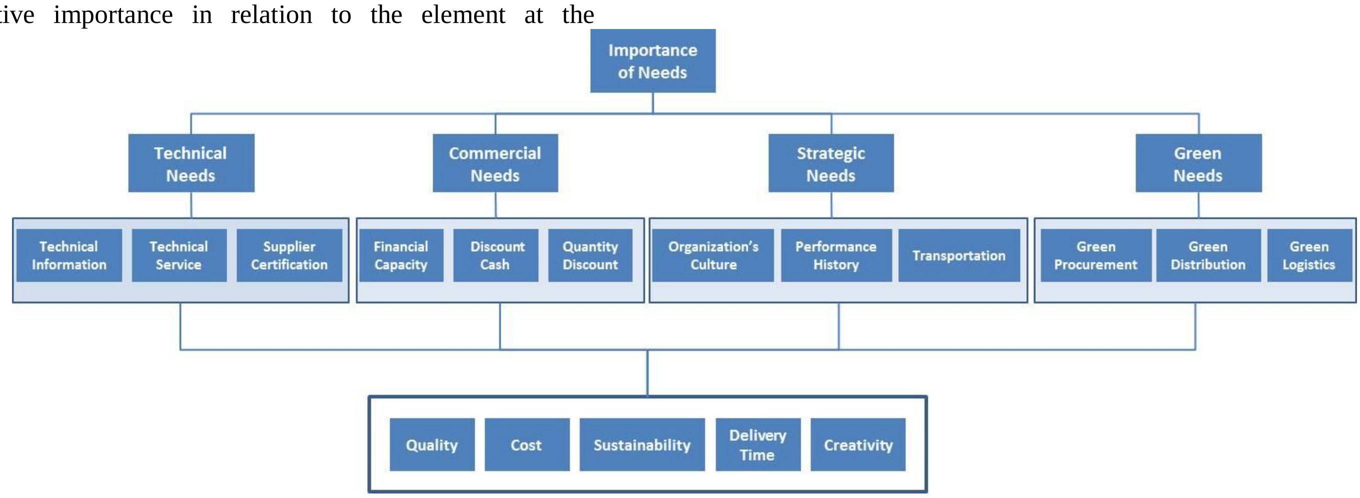


Fig. 2 Graphical Hierarchy for Customer Requirements in Hygienic Company.

4.6. QFD and AHP in the Hygienic Industry

The Quality Function Deployment (QFD) process aims to satisfy customer preferences. This technique helps companies meet the quality they need rather than acting in response to customer complaints and primarily maintain a quality that the product should have. The implementation matrix of the quality function transforms the quality requirements into measurable attribute to evaluate supplier's needs. Dikmen,M., Birgonul,T.(2005).This matrix must meet the overall needs of customers which must be met by the capabilities of the suppliers. The Fuzzy-AHP approach, with multiple attribute and a problem solving framework and systematic procedure, is to show what the elements of each problem are. Sarrafha,K., Kazemi,A.,Alinezhad,A.(2014).

The advantages of using Fuzzy-AHP are its ability to offer solutions to nondeterministic and doubtful problems, which is its main feature compared to other multi-attribute decision methods that offer the maximum degree of certainty to the user. To make this model, we need to apply the following steps:

1: Supplier requirements.

2: A single system model would identify supplier evaluation attribute. The "evaluation attribute" derive directly from the "requirements" of the customer. In other words, in order to meet a vendor's needs, what attribute should be considered? The identification of the characteristics of the product being purchased must have internal variables or " What’s" attribute that identify and directly measure the requirements from which they are obtained.

3: The vertical vector of the requirements indicating the "importance of the weight" is a relative indication of the importance of each requirement compared to the other. For this purpose Fuzzy-AHP was used. In this phase, during the use of the judgments of the team of experts of the buyer, a comparison is made in pairs between the various requirements which ultimately leads to the vertical vector of the requirements.

4: The House of Quality (HOQ) matrix is determined and achieved using the views of the buyer's expert team. This matrix indicates to what extent the evaluation attribute are influenced by the related requirements.

5: The degree of importance of each of the evaluation attribute is reached by the total sum of the multiplication of the importance of the weight of each requirement for the equivalent element of the House of Quality (HOQ).

$$W_j = \sum_{i=1}^{m} R_{ij} \otimes W_i$$

j=1, 2,…, n, i = 1, 2, . . . , m. (6)

$$R_{ij}^* = W_j + \sum_{k=j} (T_{kj} \otimes R_{kj})$$

j=1, 2,…, n, i = 1, 2, . . . , m. (7)

Then, the degree of importance of each criterion is normalized on a scale of 100 so as to reach the weight of the importance of each criterion in the supplier selection model.

$$W_{jN} = \left(\frac{R_{ij}}{\sum_{j=1}^{n} R^*_{ij}} \right) \times 100 \quad (8)$$

T_{kj} was shown in the roof part of the HOQ. The mentioned parameters are shown in Fig. 3. Furthermore each element of R_{ij}^* was De-Fuzzified by dividing it by 3. Suppose *M* (*a*, *b*, *c*) is a triangular fuzzy number (TFN); then, the De-Fuzzified value is computed as :(a + 4b + c) / 6.

W_j= priority weight of What’s j=1, 2,…, n, i = 1, 2, . . . , m.

R_{ij} =The relationship between the i^{-th} What’s and the j^{-th} How’s. j=1, 2,…, m, i = 1, 2, . . . , n.

R_{ij}^* = priority weight for How’s,j=1, 2,…, n, i = 1, 2, . . . , m.

R_{kj} = the relative importance of the k^{-th} How’s j=1, 2,…, n.

T_{kj}=the degree of correlation between the k^{-t}h and j^{th}How’s, j=1, 2,…, n, i = 1, 2, . . . , m.

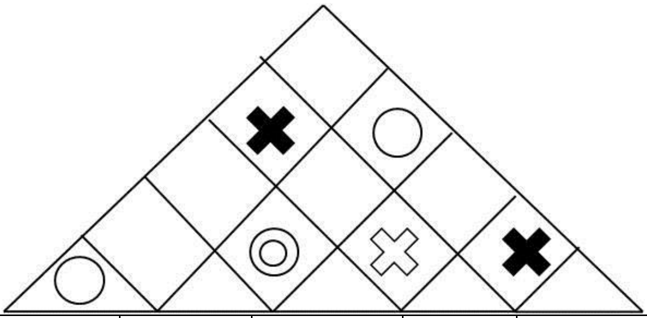
6: The model for selecting suppliers is constructed by preparing a list of supplier selection attribute together with the relative degrees of importance obtained by formula 8.

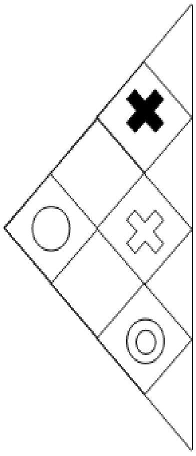
7: The "Supplier Evaluation Team" of the buyers will use Fuzzy-AHP to compare the suppliers in pairs to reach the final ranking for all the attribute for each supplier.

4.7. Weighting for Customer Requirements (What's) using Fuzzy AHP

In this paper, the rows are compared with the columns. The result of the calculations, for each matrix comparison using Fuzzy-AHP method and the comparison in pairs is shown in table 1, presented by Hou, J. (2007).

Demircan,M & Kahraman,C. (2005). The requested data were obtained from the questionnaires filled in by the buyer's expert team. The data were analysed with Fuzzy AHP with an extension analysis approach Chang,D.(2010). Each matrix corresponds to each matrix house with a factor from the row and a factor from the column. After pairwise comparison with two factors, the related results will be printed based on the triangular fuzzy numbers in the respective house. Before taking this approach, it is very important to determine whether each row or column exactly compares with the corresponding elements.





	What's	How's	Quality	Delivery Time	Sustainability	Cost	Creativity
Commercial Needs		Importance	7	4	8	8	9
	Financial Capacity	0.09	9.8	5.4	9	3.5	3.5
	Cash Discount	0.03	5.7	5.7	7.7	3.1	2.5
	Quantity Discount	0.5	2.9	6.1	7.2	7.9	6.9
Technical Needs		Importance	4	3	4	9	5
	Technical Information	0.05	3.4	2.7	1.4	3.0	3.0
	Technical Service	0.03	7.6	3.9	4.3	3.4	3.4
	Supplier Certification	0.02	1.3	7.3	2.6	1.4	3.4
Strategic Needs		Importance	5	8	4	9	7
	Organization's Culture	0.005	1.4	5.8	3.9	3.0	7.0
	Performance History	0.07	2.7	5	1.6	1.4	4.5
	Transportation	0.01	3.8	2.6	5.4	6.2	6.2
Green Needs		Importance	5	8	4	9	3
	Green Procurement	0.005	1.4	5.8	3.9	3.0	2.5
	Green Distribution	0.07	2.7	5	1.6	1.4	1.4
	Green Logistics	0.01	3.8	2.6	5.4	6.2	8.5
R_{ij} j=1, 2,…, n, i = 1, 2, . . . , m.		R_{ij}	32.7	21.5	27.7	32.6	35.9
R_{ij}^* j=1, 2,…, n, i = 1, 2, . . . , m.		R_{ij}^*	54	45	18.7	77	77
Normalize $R_{ij}^*(Nr_{ij}^*)$ [a] ,j=1, 2,…, n, i = 1, 2, . . . , m.		Nr_{ij}^*	17	27	18	20	18
Relative Weight (Priority) [b], j=1, 2,…, n, i = 1, 2, . . . , m.		Priority	17%	27%	18%	20%	18%

a Total equals 100

b Total equals 1

Fig. 3.House of Quality (HOQ).

Table 1
TFN Values (Hou, J., 2007).

Linguistic Variable	Fuzzy Number
Good (G)	(1,2,3)
Average (A)	(0.5,1.5,2.5)
Poor (P)	(0.25,1,2)
Very poor (VP)	(0.2,0.7,1.5)

4.8. Matrix of Correlations between(What's)and (How's)

The correlations of the evaluation attribute of the "How's" suppliers are constituted by the "Roof" House of Quality HOQ (Fig.3). This step in building the HOQ allows team members to continue recording how's pairs or to compare vendor evaluation attribute. Potential difficult relationships, which consequently involve measures, are inconsistent with each other. This matrix contains positive and negative correlations between pairs of "How's " that use the same symbols as Hines,P., Rich,N & Hittmeyer,M.(2015). The completed Fuzzy-HOQ is illustrated as above (Fig. 3).

4.9. ''What's'' VS ''How's'' Correlation Scores and ''How's'' Weighting

Each decision maker was asked to state an opinion, using one of the five linguistic variables, on the impact of each "How's "evaluation criterion. On each requirement of the client " What's", the opinions expressed by the ten decision makers were calculated using Fuzzy-AHP.
Again, the triangular fuzzy numbers were used to quantify the variables and the linguistic cases, the clear numbers were obtained by each decision maker from the " How's - What's" matrix. The degree of importance of each supplier was obtained by formula 9.

$$S_j = \sum_{j=1}^{n} W_{jN} \otimes e_{ij} \quad (9)$$

W_j=normalized degree of importance of j^{th} attribute, obtained from formula (8). e_{ij}= Evaluation score of j^{th} supplier's attribute in i^{th} attribute, calculated using Fuzzy AHP. j=1, 2,…, n, i = 1, 2, . . . , m.

4.10. Impact of each Potential Supplier on the Considered Attributes

After completing the weighting of each attribute, all we have to do is evaluate each supplier in front of the attribute in question and combine these assessments with the weight of each attribute in order to establish a final ranking. Tables 2 to 6 show the views of the buyers' team of experts on the various suppliers in relation to each attribute in the questionnaire. Each member of the expert team is asked to fill in the questionnaire matrix form to allow the determination of the supplier ranking.

4.11. Ranking of Supplier

There are 5 suppliers who participated in this survey. The related data were provided in each supplier selection matrix from the questionnaire. The results tabulated from 2 to 6 and presented in the form of geometric mean of the data and the reliability of each matrix was confirmed using the SPSS software. After the pair-wise comparisons for each criterion that have been made with Fuzzy-AHP and the implementation model of the QFD has been performed using EXCEL software, the suppliers are classified and finally the best is selected.

Table 2
Pair-Wise Comparison for Supplier Selection based on Quality Attribute.

Matrix 1	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
S_1	1	(0.9,1,1.7)	(0.5,1,1.8)	(0.8,1,1.2)	(0.5,1,1.2)
S_2		1	(2,2.9,3)	(2,2.3,3)	(2,2.7,3)
S_3			1	(0.3,1,2)	(1.2,2,3)
S_4				1	(2,2.9,3)
S_5					1

Table 3
Pair-Wise Comparison for Supplier Selection based on Delivery Time Attribute.

Matrix 2	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
S_1	1	(1,1.5,2)	(1,1.9,2)	(1,1.4,2)	(1.9,2,2)
S_2		1	(1.7,2,2.3)	(1.9,2,3)	(1.5,1.7,2)
S_3			1	(2,2.7,3)	(1.6,2,2.9)
S_4				1	(1,2.8,3)
S_5					1

Table 4
Pair-Wise Comparison for Supplier Selection based on Sustainability Attribute.

Matrix 3	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
S_1	1	(1,1.7,2)	(1,1.9,2)	(0.7,1,1.8)	(1,1.9,2)
S_2		1	(1,1.2,2)	(0.2,1,1.9)	(1.2,2,3)
S_3			1	(0.7,1,2)	(2,2.7,3)
S_4				1	(2,2.3,3)
S_5					1

Table 5
Pair-Wise Comparison for Supplier Selection based on Cost Attribute.

Matrix 4	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
S_1	1	(0.7,1,1.9)	(0.3,1,3)	(0.3,1,1.9)	(0.7,1,1.9)
S_2		1	(1,1.3,2)	(0.5,1,1.8)	(1,1.2,2)
S_3			1	(1.3,2,2.8)	(1,1.3,2)
S_4				1	(2,2.3,3)
S_5					1

Table 6
Pair-Wise Comparison for Supplier Selection based on Creativity Attribute.

Matrix 5	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
S_1	1	(0.5,1,2)	(0.3,2,3)	(0.3,1,2.9)	(0.7,1,2.9)
S_2		1	(1,1.3,3)	(0.5,1,1.5)	(1,2,2.2)
S_3			1	(1.9,2,2.8)	(1,1.3,5)
S_4				1	(2,2.3,4)
S_5					1

Table 7
Fuzzy AHP-QFD Model with Excel Software.

AHP-QFD	**Quality**	**Delivery Time**	***Sustainability***	**Cost**	**Creativity**	**Result**	**Rank**
Importance	17	27	18	20	18	-	
Supplier1	0.2	0.13	0.17	0.1	0.1	13.77	4
Supplier2	0.2	0.22	0.29	0.25	0.29	24.78	2
Supplier3	0.5	0.22	0.25	0.29	0.19	28.16	3
Supplier4	0.8	0.24	0.27	0.2	0.15	**31.64**	**1**[a]
Supplier5	0.2	0.07	0.04	0.2	0.1	11.81	5

[a]Selected Supplier

5. Discussion

Questionnaires were provided to determine the degree of importance of the elements required by each buyer, which was selected by the brain storming of the buyer expert team. After the completion of the questionnaires by the team of experts, the geometric mean was then used to calculate the data. Then the pairwise comparison of these obtained data is used in the EXCEL software. The weight priorities of the customer's requirements are calculated by programming in the EXCEL Visual Basic function. A case study was presented to illustrate the proposed approach. The processing of data indicates that technical information is of the utmost importance, followed by technical services and services. Hence, strategy and organizational culture are important, respectively.

It becomes evident, in fact, that the ultimate goal of the company is to have access to suppliers that guarantee a certain quality standard, in terms of characteristics of the products or services purchased. M,Bevilacqua et al. (2010).

In this document, an integrated "Fuzzy AHP-QFD" approach has been proposed to evaluate and select suppliers. The Fuzzy AHP method was used to determine the weight of the vendor's requirements. The use of fuzzy logic allows decision-makers to eliminate problems resulting from the subjective and unclear nature of the data, therefore the data can be formally processed.

The first steps in this direction are to determine the requirements of hygienic companies which, using previous

purchases and experience, are obtained by brainstorming meetings between shareholders and experts of the company. The resulting requirements are classified into 4 groups: Technical, Commercial, Green and Strategic Requirements.
The supplier certification has a lot of advantages on the selection of suppliers, and the status and reputation of the sector, the history of performance, the financial offer and the financial capacity have a similar influence. The other supplier requirements (What's), according to the degree of importance, are found later. The construction of a House of Quality (HOQ) allows to identify with precision each characteristic of the supplier is able to satisfy the requirements established for the product purchased outside the company; that done, drawing up a list of suppliers, it was applied. Mandal, A., Deshmukh,S.(2014).The proposed method tries to aggregate the opinions of the decision makers in a different way than the other supplier selection methods, in order to satisfy the selection of suppliers. In addition, the construction of the roof of the House of Quality (HOQ), by studying the correlations between pairs of "How's", helped decision makers to define the opinions on suppliers and to interpret the final ranking. The result obtained from the new supplier selection model mentioned above shows that supplier 4 is the most important supplier, followed by supplier 2 and therefore by supplier 3 and supplier 1 and that supplier 5 is the least important (Table 7). More clearly, to deal well with the construction of HOQ, relationships and correlations, all W_i,i = 1, 2, . . . , m.Relative Importance (R_{ij}) j=1, 2,…, n, i = 1, 2, . . . , mand priority weights(R_{ij} *)j=1, 2,…, n, i = 1, 2, . . . , m. of the attribute (How's) have been defined. The normalized ratings are obtained for the clear case by dividing all the ratings by their maximum value.

6. Conclusion

Fuzzy AHP is an effective problem solving methodology. Decision-making may involve social, economic, technical and politic factors that need to be evaluated by linguistic variables. If the environment where the decision-making process takes place is fuzzy, then fuzzy numbers are used in the assessment process. In addition, a simple software or procedure can be developed to simplify the calculations. For the purposes of this research, the Excel software was utilized in combination with the Visual Basic software for determining the weight of the each pair-wise comparison.
In this study Fuzzy-AHP method are used to determine the weight of the customer requirements. Customer requirements (What's) linguistic and subjective evaluations take place in questionnaire form. Each linguistic variable has its own numerical value in the predefined scale. In classical Analytic Hierarchy Process (AHP) these numerical values are exact numbers whereas in Fuzzy-AHP method they are intervals between two numbers. Linguistic values can change from person to person. In these situations, taking the fuzziness into account will provide less risky decisions.
Although the ability of decision making is improved by using the Fuzzy AHP, but the evaluation of the buyer expert team judgment consistency is more difficult than the crisp expert team judgment of the buyer. Because, in this method it is necessary to measure the consistency in the range of numbers. In this study, in order to evaluate the consistency of the matrices, first, the fuzzy numbers were transformed into crisp scales and then, by using the Consistency Ratio (CR) in Analytic Hierarchy Process (AHP) which is generally acceptable the evaluation of the acceptance of the results were fulfilled.($CR \leq 0.1$)
Determination and evaluation of the attribute for supplier selection in hygienic company can be affected by the characteristics of the Standard organization and Medical Department of the Ministry of Health so based on the experience of the expert team, they have been selected. If a multi-attribute decision making method with linguistic evaluations is selected for supplier selection, the Fuzzy AHP or similar methods concerning fuzzy conditions can be utilized.
The Quality Function Deployment (QFD) multi-attribute decisional method, designed to support the development of products conforming to the customer's needs and requirements, was applied to the problem of supplier selection for a hygienic company. In this general picture, the QFD and the HOQ in particular have demonstrated their potential as key tools for reconciling conventional needs (which remain important) with assessment attribute of the supplier's attributes.
Therefore, with the combination of Fuzzy AHP and QFD method, suppliers are ranked based on the final requirements of the organization that they are measured with some attribute such as Quality, Sustainability, Delivery Time, Creativity and Cost in a hygienic company.
The focus of attention for future researches will be on the integration of useful methods with QFD to prioritize a company's attribute. Future researches can also consider utilizing other ranking methods instead of the Fuzzy AHP, such as Fuzzy TOPSIS, Fuzzy ANP and so on to prioritize the company requirements and compute their priority weights. Moreover, W_i,i=1,2,…,m, i.e. What'spriority weights, obtained from different ranking methods, can be compared.
In this paper, a case study of a company in the hygienic industry was presented. More case studies for other hygienic company can be presented.by combining this method with Data Envelopment Analysis (DEA) model, the purchase can be divided between a numbers of suppliers in a way to maximize the worth of the purchase and quality besides the minimum of costs, delivery time and so on.

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