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The Design of Modeling Goal Programming - Analytic Network Process (GP-ANP) in QFD for New Product Design

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ABSTRACT

For new product development, quality function deployment (QFD) is a useful approach for translating the needs of the customer(CNs) into Technical Requirements (TRs) to achieve higher customer satisfaction. in other words ,for building House Of Quality (HOQ) is considered affect Customer Needs(CNs) , and then constructs the relation strength between (CNs) and (TRs) and the relationship between the (TRs) themselves. In this paper, an integrated framework based on fuzzy-QFD and a goal programming model is proposed to determine the technical requirements (TRs) in the House Of Quality (HOQ). The coefficients of the mathematical model are obtained from a fuzzy analytic network process (ANP) approach. Furthermore, the proposed analytic procedure should take into account the multi-objective nature of the problem, and thus, incorporate other goals such as cost , extendibility, technological feasibility and competitiveness of TRs.A zero–one goal programming methodology that includes importance levels of TRs derived using the fuzzy ANP, cost budget , extendibility level , technological feasibility level and competitiveness level goals as systemic constraints to determine the TRs to be considered in designing the product. An application for TAJ dishes washing machine powder with the smell of Grapefruit in BEHDAD Company producing detergent products with assistance of six person teams of QFD for 9 month is presented to illustrate the proposed framework.

KEYWORDS: Quality Function Deployment (fuzzy-QFD), House Of Quality(HOQ), fuzzy ANP(FANP), zero–one goal programming (GP).

1. INTRODUCTION

Providing a vague definition of the product leads to its failure or elongation of its developing process in market; however understanding the customers' needs (CNs) helps us to introduce a successful product to the market at the least possible time [4].QFD is a managerial instrument which helps the teams to concentrate on the CNs ,good or service development, marketing and the product management through a continuous process. In fact, the main goal of the QFD approach is helping the planners to concentrate on the goods and services' characteristics from the viewpoint of the market sections[6]; achieving the high level of the customer satisfaction and translating the customers' ideal into the appropriate elements in product designing and engineering, and consequently into the parts characteristics(PCs), the process planning and designing requirements (DRs) [7].The present research aims at developing an algorithm for modern and effective decision making for expanding the quality performance in a mathematical model. This algorithm is due to determine the technical requirements of the designing with regard to the all factors affecting a technical need based on the organization and the product under study in one hand, and minimizing the technical requirements of designing on the other hand. It consists of 14 steps implemented using a combination of the two decision making techniques: Analysis of the Network Process (ANP) and Zero-One Goal Programming (ZOGP) [5, 15].The suggested algorithm is dividable into two general sections. At the first process the resulted HOQ is completed for the product using FANP approach; then the results of the first process are integrated through a ZOGP model, in order to determine the technical requirements which should be focused in designing procedures. The powerful ANP instrument is considered as one of the main goals of the decision framework in this research. It consists of a fuzzy approach which permits modeling from the internal relations of the good HOQ and is used to realize the customer ideals in HOQ. On the other hand, it is necessary that the other goals and designing parameters (the second type) including the resource restrictions to consider a technical requirement satisfaction possibility through technology, its development possibility and its competitiveness rate. Each unit's monetary expenditure is determined according to the technical requirements and the priorities are specified based on the goals through pairwise comparisons and using the triangular fuzzy numbers (TFNs). Here, the approximate priorities of the technical requirements are calculated with regard to the goals and for devotion to the relations inside the house. Also, it is necessary to determine the relative importance of the weights for each goal. Finally, all calculating data gathered for formulating the zero and one goal programming model are integrated to specify those technical requirements that should be considered by the designing team. It must to be noted that in various steps. Two software have been applied because of the vast data complicated calculations and extent

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analysis process technique. In calculation section related to the network analysis process the extent analysis method was used and to specify the importance weights and to solve the ultimate model of the research which contains a zero and one goal programming(GP) the Excel and Lingo software were applied respectively. This paper consists of 7 sections. Section 2 is the QFD history; Section 3 explains various QFD approaches and the HOQ. ANP basics and watch super matrix method are presented in section 4, Decision algorithm has been explained in section 5. Sections 6 and 7 have been devoted to goal programming(GP), implementation of the decision algorithm and the modeling procedures. At last the model results have been considered.

2-QFD history

Historically, QFD has been appeared in Japan as a concept for developing new products. It has been created based on the general quality control. The first related subjects were published in 1960 by shigeru Minzono and Yugi Akao[9]. Oshiomi provided the process guarantee parameters table in Bridgestone Tire Company in 1966. These tables show the relation between quality characteristics and process factors. This idea was tested in a number of companies, but not generalized [13]. QFD was applied in Kobe shipyard company in Japan for the first time in 1967[12]. Many new concepts, particularly separate forms of the QFD, such as fuzzy QFD, developed QFD, dynamic QFD and concurrent function deployment have been matured in Japan [17]. The application of this theory extended to the individual organizations in various industries; they would be explained in following sections [6]. After a 4-year development period and testing and amending, this case study was applied successfully in manufacturing small vans in Toyota Aouto body. Consequently, Toyota could decrease its new van production about 20 per cent (1977-1979). This cost reduction reached to 38 and 61 percents in 1982 and 1984 respectively.

3- Four-Matrix Approaches

QFD approaches vary apparently, but their ultimate purpose is understanding and translating the customer's quality requirements in a technical and engineering language. In this research we emphasize on four-matrix model which is more prevalent than any other QFD methods, because of its simple application and briefness. In this method, the HOQ changes into another one in which the outputs of a matrix is the next one's input and so quality extents systematically from the good planning to manufacturing and assembling [16]. According to fig.1, the input of the first matrix in HOQ is the customer needs. It shows the customers' criteria for performance, duty, aesthetic, appearance and sentiment this house is superior than other ones [17].

This approach consists of four matrices (fig.1)

1- Product planning (HOQ): It translates the CRs into the Engineering characteristics(ECs).

2- Parts deployment: It translates ECs into the parts characteristics (PCs)

3- Process planning: It translates parts and components into the process parameters.

4- Production planning (process control planning):

The key parameters transit the process into the control points and the manufacturing operations.

4-Fuzzy ANP and its application in QFD

Analytic Hierarchy process (AHP) is of the most famous multi-criterion decision making techniques which was invented by Thomas l. Saaty in 1970. It is based on the pairwise comparisons. According to the correlation principle in AHP method, the elements of each level depend just on those of the higher level. In fact AHP uses one directional relation among the decision levels; however, ANP provides the situation for considering the mutual (two directional) relations and the decision criteria in a more general way. This overcomes the AHP deficiencies. That is why the suggested approach has been applied [1,14].

5- Decision Algorithm

The suggested algorithm may be divided into two sections. The first process contains 8 steps in which the HOQ achieved by the fuzzy ANP approach is completed for the product (Taj dish washer powder); then the second process integrates the results of the first process using a ZOGP model, in order to determine those technical requirements which must be concentrated during planning processes. Fig.2 summarizes the 13 processes of the research's decision algorithm. It must be noted the processes related to the pairwise comparisons are conducted using triangular fuzzy numbers and the Chang extent analysis method[1].

The super matrix of the model used in this research is as follow:

$$W=\begin{bmatrix} G & CNs & TRs \\ 0 & 0 & 0 \\ W1 & W2 & 0 \\ 0 & W3 & W4 \end{bmatrix}$$

In this matrix:

W1: is the vector of the effect of the goal on the customer's needs (the goal is achieving the best design and manufacturing the product which satisfies the customer's need.

W2: is the effect of the customer's needs on each technical requirement.

W3: is the indicator of the internal dependency in customer's needs and, w4 is the internal dependency in technical requirements. The network display of the QFD model in this research is based on a hierarchy structure with the components internal dependencies and without any feedback (fig.3). So the customer needs form the criteria and the technical requirements form the decision choices in ANP standard structure for the HOQ.

6- Goal programming (GP)

GP was first invented by Ignizio and Lee[4].In this research, a ZOGP has been selected as a decision making instrument, because it can combine multiple goals and search for minimizing general deviation from the design foals[3]. Such characteristics of GP enable us to incorporate the multiple goals as resources restrictions, technological possibility for a technical need etc in planning process.

eneral form of the GP model applied in this paper is as follow [8 and 11]:

$$MinD = W1^{ANP} + \sum_{i=2}^{s} Wi\left(\frac{di^{-}}{Ri} + \frac{di^{+}}{Ri}\right) + \sum_{i=s+1}^{m} Wi(di^{-})$$

s.t:

$$\sum_{j=1}^{m} wj^{ANP}\, Xj + d1^{-} -= 1$$

$$\sum_{j=1}^{n} rijxj + di^{-} - di^{+} = Ri \quad ; i = 2, \ldots . s$$

$$\sum_{j=1}^{n} wijxj + di^{-} - di^{+} = 1 \quad ; i = s + 1, \ldots, m$$

$$xj \in \{0, 1\}, j = 1, \ldots, n\ di^{+}, di^{-} \geq 0, i = 1, \ldots, m$$

Where:

Wi: is the goals weights in GP; di+,di-(i=1,…,m) : shows th negative and positive deviations variables of the i^{th} goal(i=1,…,m),

Xj: is the zero and one variable and shows the j^{th} technical characteristic of the product (j=1,…,m)

$\mathbf{w_j^{ANP}}$: shows the dependency priority of the j^{th} technical characteristic of the product (j=1,…,n).

Rij: is an amount of ith resource consumed by ith technical characteristic (i=2,…,s;J=1, …,n).

Ri: shows the i^{th} resource restriction, and wij: is the relative importance of the j^{th} technical characteristic with regard to the goal (i=s+1,…,m;j=1,…,n).

7- Implementation of the decision algorithm the decision:

algorithm applied in this research 5. Now we consider the implementation of this algorithm for the Taj dish washer powder.

First step- Recognition of the customer needs and the related technical requirements and determining their relations.

Identification of customers' needs (WHATs). Needs and preferences of customers or in other words, customer's voice, is the beginning of QFD process and quality house. Customers' wants announces the company what to do. Through the methods such as Focus Groups, individual interviews, filling out and sending questionnaires by customers, reviewing complaints and unconformities and etc, qualitative wants of customers are determined and compiled. Individual interview with customers is performed via Character Focus Group so that interviews with 20 to 30 customers covers circa 90 to 95 percent of customers' wants.The customer needs have been extracted through completing the customers' questionnaires and the related interviews conducted by QFD teams. They are presented in table1(CN1 to CN8).

Identification of technical properties of product (HOWs). Technical properties of product or engineering factors determine the production process conformed to customers' preferences. Technical properties, according to customers' wants, tell the company how to design the product. The properties should be measurable. Tree diagram and affinity diagram can be adopted to determine and compile technical properties. Following the agreement of the team members on the customer's needs, it's turn to determine the technical requirements with the highest effects on the customer. Table 2 shows a summary of technical requirements (TR1 to TR8).

Fig.4 shows the relations inside the HOQ and the relations among the technical requirements achieved through interview with the experts of the QFD Team.

After recognition and classification, customer’s wants and technical properties are placed in the left side and top of the quality house, respectively.

step2- determining the relative importance of the customer's needs using the verbal data Assuming

Ranking customers’ wants. As it is impossible to meet all wants of customers because of technical and budget limitations, the wants need to be prioritized in order to meet more important ones. Company should neglect and postpone meeting some wants. In order to assign relative importance of each of the wants of customers, telephone interview, fax, or e-mail can be utilized through 1-5, 7, 9 or 1-10 spectra.

no dependence among the customer's needs the QFD team members were asked to apply verbal scale and the triangular fuzzy numbers in order to achieve the relative importance of each customer's need. They were due to compare the customer's needs pairwisely aiming at achieving the best design for the Taj powder. The results of the questionnaires are integrated and then the extent analysis method applied (vector w1):

$$W_1=\begin{bmatrix} CN1 \\ CN2 \\ CN3 \\ CN4 \\ CN5 \\ CN6 \\ CN7 \\ CN8 \end{bmatrix}=\begin{bmatrix} 0.257 \\ 0.122 \\ 0.110 \\ 0.154 \\ 0.134 \\ 0.122 \\ 0.04 \\ 0.061 \end{bmatrix}$$

W1 vector shows the relative importance of the customer's needs. As you see they are prioritized as follows: Cleaning power, cleaning the oily stains, to make glittering, preventing from incrustation and foods' had fragrance, disinfect and solubility.

Step3- determining the relative importance degrees of the technical requirements using Verbal scale.

Now, assuming no dependence among the technical requirements, as the previous step, we determine the relative importance degree of the technical requirement with regard to the each customer's need. For instance, to determine the relation between the customer's need (cleaning power) and the related technical characteristics, we may ask:

How much is the relative importance degree of phosphate in comparison to nonionic, with regard to the cleaning power?

Table 3, shows the results of such pairwise comparison for each customer's need after integrating the all experts' responses.

Tble3- A measurement of the relative importance degree for the cleaning power in comparison to the related technical requirements

Wj	silicate	Enzyme	nonionic	Phosphate	the power of washer
0.203	(.45,.75,1.08)	(.45,.75,1.08)	(.98,1.25,1.58)	(1,1,1)	Phosphate
0.299	(1.25,1.75,2.25)	(.75,1.25,1.75)	(1,1,1)	(.63,08,1.05)	nonionic
0.292	(1.25,1.75,2.25)	(1,1,1)	(.57,.8,1.33)	(.92,1.33,2.22)	enzyme
0.206	(1,1,1)	(.44,.57,.8)	(.44,.57,.8)	(.92,1.33,2.22)	silicate

Identification of relationship between customers’ wants and technical properties. This step determines how and to what extent each technical property is assigned with each of customers’ wants. The relationship between customers’ wants and technical properties can be shown through either conventional signs or numbers. The present paper utilized numbers to depict the relationships.

W2 matrix is formed by inserting vectors achieved by each table (wj). This matrix shows the weights of the technical characteristics' relative importance, with regard to the customer's needs.

$$W2 - \begin{bmatrix} 0.203 & 0 & 0 & 0.118 & 0 & 0 & 0 & 1 \\ 0.299 & 0 & 0.5 & 0 & 0 & 0.945 & 0 & 0 \\ 0.292 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.5 & 0 & 0 & 0 & 0 & 0 \\ 0.206 & 0 & 0 & 0.882 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.055 & 0 & 0 \end{bmatrix}$$

Step4- determining internal correlation matrix for the customer's needs.

Identification of inter-correlation of customers' wants. Sometimes inter-correlation occurs in customers' wants. Some wants support many other wants. On the contrary, some have adverse effects on other wants; in other words, they have antagonistic relationship. These types of inter-correlations can be shown in terms of a matrix, conformed to W3 matrix which is the sign of trade-off and balance between the wants.

This matrix (w3) would be achieved by the effect of each need on the customer's needs and these needs relation of the customer's needs achieved by QFD experts' opinion. Fig.5 shows the related schema needs.

$$W3 = \begin{bmatrix} 0.183 & 0.261 & 0.394 & 0 & 0.613 & 0.412 & 1 & 0.324 \\ 0.211 & 0.178 & 0 & 0 & 0.387 & 0 & 0 & 0.309 \\ 0.184 & 0.183 & 0.194 & 0.308 & 0 & 0.313 & 0 & 0 \\ 0 & 0 & 0 & 0.237 & 0 & 0 & 0 & 0.177 \\ 0.225 & 0.188 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.213 & 0.161 & 0 & 0.275 & 0 & 0 \\ 0.103 & 0.076 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.094 & 0.114 & 0.199 & 0.294 & 0 & 0 & 0 & 0.190 \end{bmatrix}$$

Step5- determining the internal correlation matrix of the technical needs.

Identification of inter-correlation of technical properties. Sometimes an increased or decreased technical property has a direct effect on other properties of the product. In some cases, technical properties antagonize each other where over-consideration of one results in negligence of other. In such cases, formation of a trade-off is regarded as the easiest remedy. To create correlation between the product's properties in the matrix roof, the correlation rates are depicted through signs or numbers.

Again in this step, the QFD team members' opinion has been collected to determine the internal relations of the designing requirements. Fig.6 shows the related schema.

Then we achieve w4 matrix as in previous steps.

$$W4 = \begin{bmatrix} 0.189 & 0.492 & 0.200 & 0.684 & 0 & 0.200 & 0 & 0 \\ 0.208 & 0.436 & 0.285 & 0 & 0 & 0.198 & 0 & 0 \\ 0.222 & 0 & 0.270 & 0 & 0 & 0.218 & 0 & 0 \\ 0.148 & 0 & 0 & 0.316 & 0 & 0.172 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0.233 & 0.072 & 0.245 & 0 & 0 & 0.212 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Setep6- determining the mutual dependence priorities of the customer's needs.

The mutual dependence priorities of the customer's needs (w_C) are achieved by the information collected in previous steps as follow:

$$Wc = W3 \times W1 = \begin{bmatrix} CN1 \\ CN2 \\ CN3 \\ CN4 \\ CN5 \\ CN6 \\ CN7 \\ CN8 \end{bmatrix} = \begin{bmatrix} 0.415 \\ 0.159 \\ 0.118 \\ 0.077 \\ 0.021 \\ 0.078 \\ 0.009 \\ 0.123 \end{bmatrix}$$

Step7-determining the mutual dependence priorities of the technical requirements

The mutual dependence priorities of the technical requirements (W_A) are calculated as follow:

$$WA = W4 \times W2 = \begin{bmatrix} 0 & 0 & 0.200 & 0 & 0.684 & 0.200 & 0.496 & 0.189 \\ 0 & 0 & 0.198 & 0 & 0 & 0.285 & 0.437 & 0.208 \\ 0 & 0 & 0.218 & 0 & 0 & 0.270 & 0 & 0.222 \\ 0 & 0 & 0.172 & 0 & 0.316 & 0 & 0 & 0.148 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.212 & 0 & 0 & 0.072 & 0.072 & 0.233 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Step8-determining of general priorities of technical properties and other general objectives in product design

In this part, the obtained results from the previous parts are adopted for final prioritizing technical properties of the product. Also, other designing criteria such as cost, constructability, development capacity, resources limitation, etc, may be brought into this part. Although the criteria may be considered as being extra information for quality house, they are of great help for identification and improvement of priorities and also as an objective product to be assured of met wants.

When technical properties of the product (that are to be changed) are identified, the properties are transferred to the next matrix as “WHATs” for recognition of critical properties of pieces and parts. Construction operation, daily operation and control points are defined in a same way.

Finally, total priorities of technical properties are obtained considering total relative weights of customer’s wants (i.e. W^{ANP}) which reflects total relations inside the quality house (Figure 7).

$$W^{AHP} = W2 \times W1 = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.285 \\ 0.183 \\ 0.058 \\ 0.061 \\ 0.131 \\ 0.122 \\ 0.154 \\ 0.006 \end{bmatrix} \begin{matrix} 1 \\ 2 \\ 7 \\ 6 \\ 4 \\ 5 \\ 3 \\ 8 \end{matrix} \qquad W^{ANP} = WA \times WC = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.110 \\ 0.089 \\ 0.054 \\ 0.023 \\ 0.039 \\ 0.056 \\ 0.187 \\ 0.442 \end{bmatrix} \begin{matrix} 3 \\ 4 \\ 6 \\ 8 \\ 7 \\ 5 \\ 2 \\ 1 \end{matrix}$$

Table4 shows the results of the two approaches:

In fuzzy AHP approach, Benzotriazole with the importance degree o.oo6 has been recognized as the minimum degree, while this technical requirement in Fuzzy ANP approach with the importance degree o.442 is the maximum level.

Step9-recognision of the criteria and restrictions related to the organizational resources

An estimation of person-resources needed for making or correcting each of technical properties are provided like matrix *b*. on the other hand, total allocable budget by company for development of dish-washing powder is 4500 Rls person-hour considering number of customer’s needs and wants.

$$b = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 590 \\ 850 \\ 387 \\ 487 \\ 720 \\ 544 \\ 470 \\ 452 \end{bmatrix}$$

Step 10- determining the preferential cost of the designing requirements with regard to the second type goals.

Other than budget and human force, other objectives should also be considered to design the considered product.in this research Technological possibility (T), extent ability (E) and competition degree(C) of a need were selected as the considerable second type parameters for determining the designing goals of Taj, based on the experts' opinions and the QFD team members' agreement. These parameters have been defined as follows:

1-Technological possibility:

To what extent can one observe the technical characteristics in production without any technological change?

2-Extentability level: To what extent does the improvement of a technical need lead to improvement of the future needs?

3- Competiveness level: To what extent does a need create competitive advantage?

The importance weights matrix for each need has been shown as follow with regard to the parameters:

$$W^T = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.145 \\ 0.130 \\ 0.111 \\ 0.129 \\ 0.107 \\ 0.125 \\ 0.108 \\ 0.145 \end{bmatrix} \quad W^E = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.138 \\ 0.141 \\ 0.104 \\ 0.112 \\ 0.090 \\ 0.130 \\ 0.148 \\ 0.137 \end{bmatrix} \quad W^C = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.158 \\ 0.175 \\ 0.177 \\ 0.106 \\ 0.070 \\ 0.096 \\ 0.082 \\ 0.136 \end{bmatrix}$$

As you see in matrix W^T, the technical characteristics of phosphate and benzotriazole with the same importance degree have commonly maximum degree and silicate has the minimum technological possibility degree. Also, with regard to matrix w^E, essence and silicate have the highest and lowest extentability respectively. Finally, according to matrix w^c , the maximum and minimum competitive degree pertain to enzyme and silicate respectively

Step11- Justifying the resource restriction and another designing goals

Weight arrows related to resources limitation, development capability, compatibility and technological feasibility, which were estimated in ninth and tenth steps, should reflect the inter-correlations and –affinities in technical properties of dish-washing powder shown in the roof of quality house.

In order to integrate inter-affinities of technical properties and weight arrow of budget for changing and correcting technical properties, the matrix showing the inter-affinities of technical properties (W_4) is multiplied by the arrow showing needed budget for technical properties (*b*) estimated in ninth step in order to obtain enhanced arrow of needed budget for technical properties (b').

In a same manner, W_4 matrix is multiplied by relative weights arrow of development capability (W^E) to acquire development capability of technical properties ($W^{E'}$). Also, to obtain enhanced arrow of technological feasibility of technical properties ($W^{T'}$), W_4 matrix is multiplied by relative weights arrow of constructability (W^T).

Finally, to obtain enhanced arrow of compatibility of technical properties ($W^{C'}$), W_4 matrix is multiplied by relative weights arrow of compatibility (W^C).

$$b' = w4 \times b = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 995.348 \\ 530.602 \\ 231.468 \\ 360.98 \\ 487 \\ 354.48 \\ 850 \\ 590 \end{bmatrix} \qquad W^{T'} = W_4 \times W^T = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.201 \\ 0.135 \\ 0.090 \\ 0.074 \\ 0.129 \\ 0.096 \\ 0.130 \\ 0.145 \end{bmatrix}$$

$$W^{C'} = W_4 \times W^C = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.169 \\ 0.126 \\ 0.095 \\ 0.073 \\ 0.106 \\ 0.099 \\ 0.175 \\ 0.158 \end{bmatrix} \qquad W^{E'} = W_4 \times W^E = \begin{bmatrix} TR1 \\ TR2 \\ TR3 \\ TR4 \\ TR5 \\ TR6 \\ TR7 \\ TR8 \end{bmatrix} = \begin{bmatrix} 0.207 \\ 0.151 \\ 0.088 \\ 0.067 \\ 0.112 \\ 0.096 \\ 0.141 \\ 0.138 \end{bmatrix}$$

Based on the information achieved by now, we may build HOQ. Fig.7 shows the house of quality for the Taj dish washer powder.

step12-determining the weights of the in designing goals

Relative importance The designing goals for the Taj dish washer powder which form the subordinate elements of the GP model are: considering all available internal relations in the HOQ of the Taj dish washer powder, the organizational financial resource restrictions, technological possibility of the technical requirements, extentability of the technical requirements and competitive degree of the technical requirements. Since these foals have unequal importance in decision making process, it is required that their relative importance weights to be specified and reflected in the goal function of the GP model. The team members' opinions have been collected to measure these criteria's relative weights through pairwise comparisons.

Then, they are normalized and presented as follow:

$W_{GS}=$

Internal dependency of House Of Quality	**0.213**
resource restrictions	0.213
technological possibility	0.203
Extentability level	0.175
Competiveness	0.196

step13- Formulation and solving the zero and one goal programing.

With regard to the completed HOQ(fig.7) and the relative weights of the designing criteria(W_{Gs}), we achieve the zero- one goal programming(GP) model in order to determine the technical characteristics through applying Lingo software; therefore:

$$\text{Min } 0.213\, d_1^- + 0.213\, d_2^+ + 0.203\, d_3^- + 0.175\, d_4^- + 0.196\, d_5^-$$

ST:

$$0.110\, X_1 + 0.089\, X_2 + 0.054\, X_3 + 0.023\, X_4 + 0.039\, X_5 + 0.056\, X_6 + 0.187\, X_7 + 0.442 X_8 - d_1^+ + d_1^- = 1$$

$$(348.995\, X_1 + 530.602\, X_2 + 0.054\, X_3 + 231.468\, X_4 + 487\, X_5 + 354.480\, X_6 + 850\, X_7 + 590\, X_8 - d_2^+ + d_2^-)/4000 = 1$$

$$0.203\, X_1 + 0.135\, X_2 + 0.090\, X_3 + 0.074\, X_4 + 0.129\, X_5 + 0.096\, X_6 + 0.130\, X_7 + 0.145 X_8 - d_3^+ + d_3^- = 1$$

$$0.207\, X_1 + 0.151\, X_2 + 0.088\, X_3 + 0.076\, X_4 + 0.112\, X_5 + 0.096\, X_6 + 0.141\, X_7 + 0.138 X_8 - d_4^+ + d_4^- = 1$$

$$0.169\, X_1 + 0.126\, X_2 + 0.095\, X_3 + 0.073\, X_4 + 0.106\, X_5 + 0.099\, X_6 + 0.175\, X_7 + 0.158\, X_8 - d_5^+ + d_5^- = 1$$

$$Xj = 0, 1 \; (j=1,2,\dots,8) \qquad di^+, di- \geq 0 \quad (i=1,2,3,4,5)$$

As you see this model consists of their main sections: decision variables, target function and system limitations[3].Here, $x_1,x_2,x_3,\dots,x_8$ are the decision variables or the technical characteristics. This model has five limitations:

First, priorities of the technical characteristics resulted from implementing the fuzzy ANP method: The right amount of this ANP method. The right amount of this limitation is at most one, therefore d1- (deviation from the ANP criteria and goals) is minimal.

Second, limitation of the available financial sources: Sine there is a maximum application level; then the d2+ must be minimal. The right of this limitation shows the available budget according to the present information as 2000 Rials.

Third, this limitation shows the importance weights of the technical characteristics with regard to the each need's technological possibility. In this limitation d3-(unfavorable deviation from the technological possibility rate) would be minimal.

Fourth, each technical characteristic's relative importance weight with regard to the extendibility rate in this limitation: According to the target function, d4-(unfavorable deviation from the extentability rate) is minimal.

Fifth, limitation out of each technical requirement's relative importance weight with regard to competitiveness rate: According to the target function d5-(unfavorable deviation from competitiveness) would be minimal.

Since the total weights of the technical characteristic is at most one it would be zero in d^+_1, d^+_3, d^+_4,and d^+_5, we would achieve the following results through solving the model using Lingo oo,8 software for zero , one variables, and Ideal(goal) Variables.

$X_1=X_2=X_3=X_4=X_6=X_7=X_8=1 \;\; ; X_5=0$

$d_1^{\cdot}$ = 0.3900000E-01	**$d1^+ = 0$**
d_2^+ = 0.000000	d2- = 0
$d_3^{\cdot}$ = 0.1290000	$d3^+ = 0$
$d_4^{\cdot}$ = 0.1030000	$d4^+ = 0$
$d_5^{\cdot}$ = 0.1050000	$d5^+ = 0$

As it can be seen, the rates of the variables x1, … , x8 is 1 and the variable x5 is zero. That is properties of phosphate, nonionic, enzyme, phosphonate, perborate, essence and benzotriazole are chosen by model to be changed and corrected ; however, silicate properties whose variable is zero is not selected. The variables d1, d3, d4 and d5 show unfavorable deviations from the objectives, ANP criteria, technological feasibility, development capability, and compatibility, respectively. The variable d2 shows deviation from budget. In other words, this variable shows consumed budget (resource) higher than available amount which should definitely be provided to enhance and correct the properties x1 to x8.

Conclusion

After solution of ZOGP model, 7 properties were chosen among 8 technical properties for meeting 8 identified customer's wants to be changed and corrected. The company may be assured of meeting customer's wants according to the companies' abilities through changing and correcting chosen technical properties by the model. Considering the results obtained by solving the model where x1=x2=…=x8=1 and x5=0, among others, anly the silicate property has not be chosen. In other words, considering objective weights and different criteria and also considering the available budget (resources), technological feasibility, development capability and compatibility, changing and correcting it are not necessary and the company can keep the factor at the present level. However, for gaining customers' satisfaction, according to the results acquired from the model, the company should change and correct other technical properties. In other words, the company should change (increase or decrease) the technical properties x1 to x8 in a favorable way.

QFD technique is an important designing tool to make companies able to identify their customers' wants and needs and blur in necessities of product design. Like any other tool, profitability level and the advantages gained by QFD depend on how to use it effectively. In order to promote effectiveness of this technique, a systematic trend for decision-making was presented in this paper to be used in product designing trend in QFD based on viewpoints of experts and mutual comparisons. The decision-making algorithm helps to determine the relations between customers' wants and technical properties of product, their inter-correlations and resources limitations and other criteria such as technological feasibility, development capability and compatibility in product design.

In this competitive era, interactions of various viewpoints need to be welcomed and they should be adopted in order to reach integrated models in QFD process. By this, potentials of this effective tool are activated more. In this regard, the present paper used an integrated trend for ANP and ZOGP to integrate customers' wants and technical properties of product systematically in product design phase in QFD process. Inter-correlations of factors in QFD process are performed through ANP strategy in decision-making algorithm. Considering limited resources and multi-objectiveness of the problem, a ZOGP model is created in order to identify technical properties in product design phase and also to identify control points of the product. it should be noted that QFD, by itself, cannot be considered as an optimum design method. Using the weights obtained from ANP, resources limitations and other considered criteria in designing such as development capability and constructability in ZOGP model, more permissible and conformable answers are obtained. Also, designing necessities are identified in a way that maximizes customer satisfaction according to current limitations.

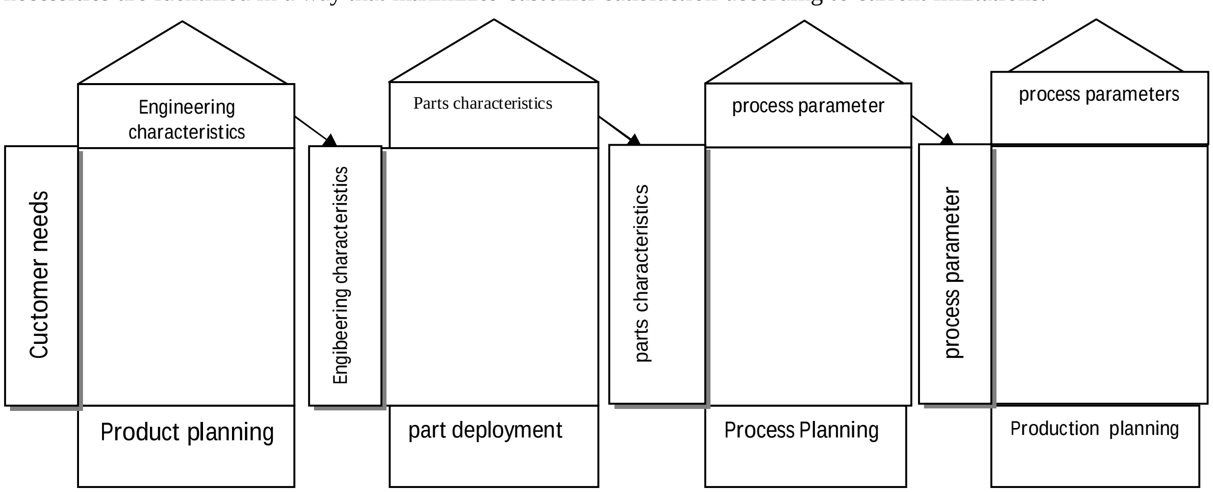


Figure 1- principles of the QFD practice using HOQ [10]

Step1	**Recognition of those customer needs affecting on them and determining the HOQ internal relations**

Step2	Determining the relative importance degrees of the customer's needs using the verbal data and assuming no dependency among them: w1 calculation
Step3	Determining the importance degrees of the technical requirements with regard to the customer's needs and using verbal data and assuming no dependency among them: w 2 calculation
Step4	Determining the internal dependency matrix of the customer's needs using verbal data and displaying the internal dependency scheme among the needs: W 3 calculation
Step5	determining the internal dependency matrix of the technical requirements using verbal data and displaying the internal dependency scheme among the needs: W 4 calculation
Step 6	determining the customer's needs priority: w1× w3=Wc calculation
Step 7	determining the technical requirements priority: w2×W4=wA calculation
Step 8	determining the general priority of the technical requirements : Wc× wA=w^{ANP} calculation
Step 9	Recognition of the measurement units and resources restrictions
Step 10	determining the preferable prices of the product's technical requirements with regard to the playing goals (here they are called the second type goals) using pairwise comparisons
Step 11	Justifying the measurement units with regard to the resources restriction and justifying the technical requirements priority with regard to the second type goals
Step12	Calculation of the goals' relative weights using the pairwise comparisons
Step 13	Formulating and solving the ZOGP model for determining the whole product technical requirements must be considered in planning phase.

Figure 2 – The research's decision evaluation algorithm steps

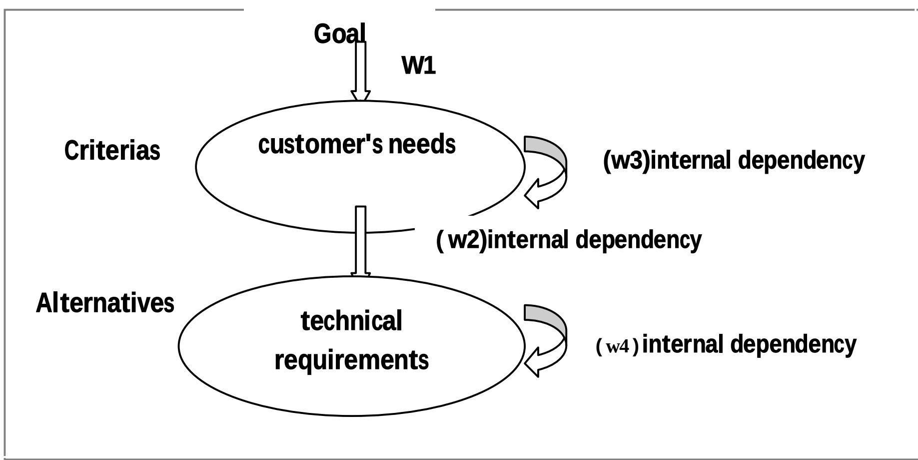


Fig 3-A view of the network QFD model

Table1- The customer's needs about the Taj dish washer powder

the power of washer	CN1
cleaning the oil stains	CN2
to make glittering	CN3
preventing from incrustation	CN4
preventing from foods' bad fragrance	CN5
preserving the silver and steel dishes' appearance,	CN6
disinfect	CN7
solubility	CN8

Table2: Technical requirements of the Taj dish washer powder

Phosphate	TR1
nonionic	TR2
enzyme	TR3
phosphonate	TR4
silicate	TR5
perborate	TR6
essence	TR7
benzotriazole	TR8

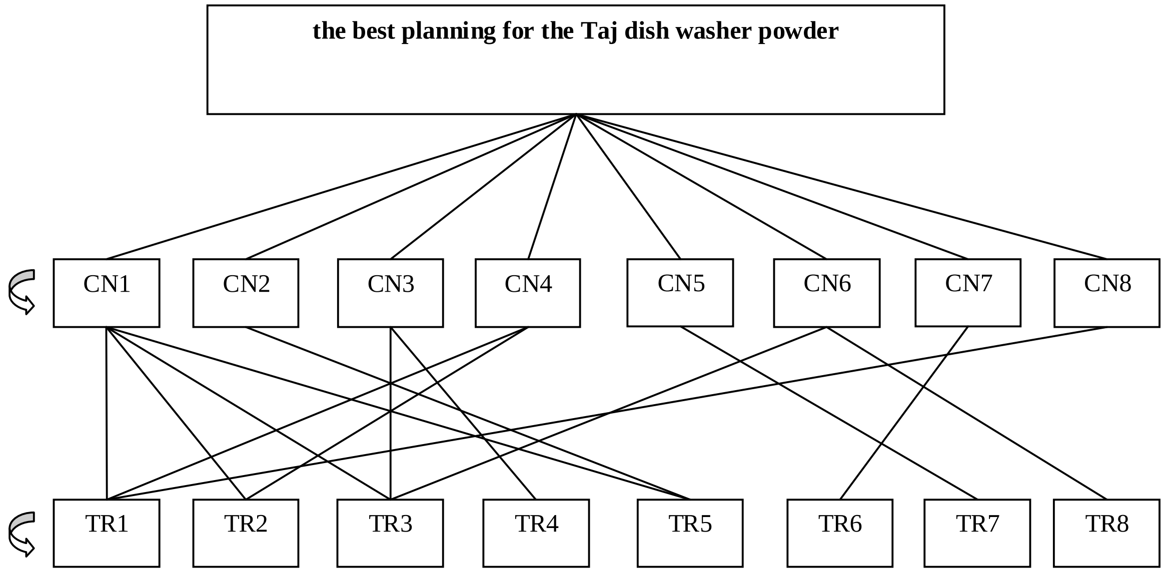


Figure4 – The network model for the HOQ of the Taj dish washer powder

Tble3- A measurement of the relative importance degree for the cleaning power in comparison to the related technical requirements

Wj	silicate	Enzyme	nonionic	Phosphate	the power of washer
0.203	(.45,.75,1.08)	(.45,.75,1.08)	(.98,1.25,1.58)	(1,1,1)	Phosphate
0.299	(1.25,1.75,2.25)	(.75,1.25,1.75)	(1,1,1)	(.63,08,1.05)	nonionic
0.292	(1.25,1.75,2.25)	(1,1,1)	(.57,.8,1.33)	(.92,1.33,2.22)	enzyme
0.206	(1,1,1)	(.44,.57,.8)	(.44,.57,.8)	(.92,1.33,2.22)	silicate

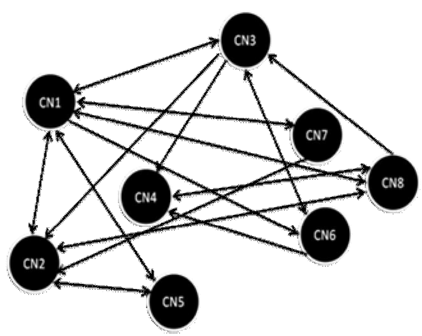


Figure5-A scheme of the internal relations of the customer's of the internal relations of the customer's needs.

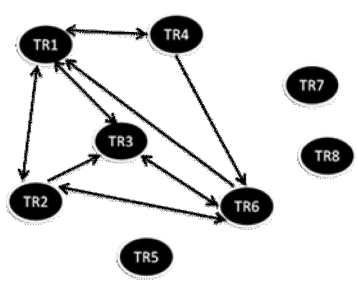
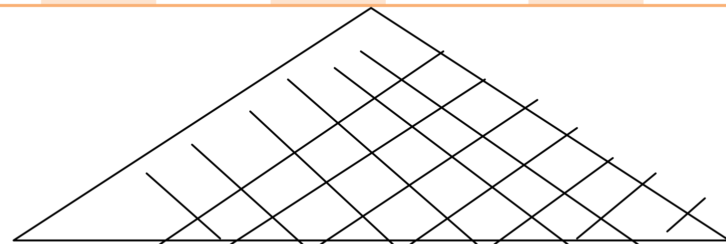
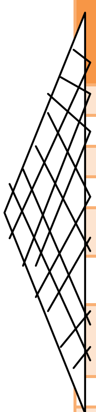


Figure6-A schema of the technical requirements' internal relations
Then we achieve w4 matrix as in previous steps.

Table 4-A comparison of the weights and ranks achieved by fuzzy AHP and ANP approaches.

TR8	TR7	TR6	TR5	TR4	TR3	TR2	TR1	Technical requirements / weights, ranks
0.4421	0.1872	0.0565	0.0397	0.0238	0.0546	0.0894	0.1103	F-ANP weights F-ANP rank
0.0068	0.1543	0.1225	0.1314	0.0616	0.0587	0.1832	0.2851	F-AHP weights F-AHP rank





	phosphate	nonionic	enzyme	phosphonate	silicate	perborate	essence	benzotriazole	Important degree
	1	2	3	4	5	6	7	8	
the power of washer	0.203	0.299	0.292		0.206				0.257
cleaning the oil stains			1						0.122
to make glittering		0.5		0.5					0.11
preventing from incrustation	0.118				0.882				0.154
preventing from foods' bad fragrance							1		0.134
preserving the silver and steel dishes' appearance,		0.945							0.122
Disinfect						1			0.04
Solubility	1								0.061
Internal dependency of House Of Quality	0.11	0.089	0.054	0.023	0.039	0.056	0.187	0.442	
Cost budjet	995.3	530.6	231.5	361	487	354.5	850	590	
technological possibility	0.201	0.135	0.09	0.074	0.129	0.096	0.13	0.145	
Extentability level	0.207	0.151	0.088	0.067	0.112	0.096	0.141	0.138	
Competiveness level	0.169	0.126	0.095	0.073	0.106	0.099	0.175	0.158	

Figure7- HOQ for the Taj dish washer powder through the research decision

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Appendix:

```
min=.213*d12+.213*d21+.203*d32+.175*d42++.196*d52;

.110*x1+.089*x2+.054*x3+.023*x4+.039*x5+.056*x6+.187*x7+.442*x8-d11+d12=1;
(995.348*x1+530.602*x2+231.468*x3+360.98*x4+487*x5+354.48*x6+850*x7+590*x8-d21+d22)/4000=1;
.201*x1+.135*x2+.090*x3+.074*x4+.129*x5+.096*x6+.130*x7+.145*x8-d31+d32=1;
.207*x1+.151*x2+.088*x3+.076*x4+.112*x5+.096*x6+.141*x7+.138*x8-d41+d42=1;
.169*x1+.126*x2+.095*x3+.073*x4+.106*x5+.099*x6+.175*x7+.158*x8-d51+d52=1;
@BIN(x1);
@BIN(x2);
@BIN(x3);
@BIN(x4);
@BIN(x5);
@BIN(x6);
@BIN(x7);
@BIN(x8);
```

Global optimal solution found at iteration: 3
Objective value: 0.7309900E-01

Variable	Value	Reduced Cost
D12	0.3900000E-01	0.000000
D21	0.000000	0.2130000
D32	0.1290000	0.000000
D42	0.1030000	0.000000
D52	0.1050000	0.000000
X1	1.000000	-0.1335820
X2	1.000000	-0.9748300E-01
X3	1.000000	-0.6379200E-01
X4	1.000000	-0.4752900E-01
X5	0.000000	-0.7487000E-01
X6	1.000000	-0.6762000E-01
X7	1.000000	-0.1251960
X8	1.000000	-0.1786990
D11	0.000000	0.2130000
D22	87.12200	0.000000
D31	0.000000	0.2030000
D41	0.000000	0.1750000
D51	0.000000	0.1960000

Row	Slack or Surplus	Dual Price
1	0.7309900E-01	-1.000000
2	0.000000	-0.2130000
3	0.000000	0.000000
4	0.000000	-0.2030000
5	0.000000	-0.1750000
6	0.000000	-0.1960000