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An Efficient ANP-BGP Model for Software Production by QFD

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Abstract: In the proposed paper an efficient model via combining QFD, Analytic Network Process (ANP), and Bounded Goal Programming (BGP) is presented to insure multiple objectives of the organization and to supply a variety of customer's needs in the process of designing, manufacturing, and providing the after sale services for software products. QFD defines customer's needs (CNs) and product's technical requirements (PTRs) regarding their interrelationships and finally ranks the technical requirements. The algorithm consists of two decision making techniques including ANP and BGP. The goal of ANP is to determine and evaluate the relationship between CNs and PTRs. ANP approach will facilitate the evaluation of interrelations between CNs and the correlation between PTRs. By ANP, this paper has introduced a BGP in order to provide the organizations multiple objectives. More over, development rate, resource constraints and the manufacturability needed to determine PTRs were all taken into considerations in designing, manufacturing and the after sale services of the model. The model results are demonstrated in a case study of producing software in Golestan Company to be evaluated.

Key words: Analytic Network Process, Quality Function Development, Bounded Goal Programming, software products.

INTRODUCTION

Clearly, regarding better conditions in the products and services quality and keeping continuous improvement in the process of development and change, are among major obsessions for the companies in the world of competitions. Quality function deployment is one of the techniques which are able to help the organization from the early stages of production process i.e. designing phase to reach the customer's satisfaction (Karask, *et al*., 2002; Revelle, 1998; Tangm, *et al*., 2002). QFD identifies the customer's needs (CNs) in a well organized framework and reveals them all in the form of product's technical requirements (PTRs), (Hunt and Xavier, 2003; Shilito, 1994).

There has been a lot of research done over designing the product of QFD in the last decade in which the main focus has always been on the customer's needs, including the application of fuzzy logic for regarding these demands (Chan, 1990; Khoo and Hu, 1996), the application of analytic hierarchical process to determine the relative importance of the customer's needs (Lu, *et al*., 1994; Park and Kim, 1998), or the application of linear programming model in the product's designing process to maximize the customer's satisfaction based on the limits of the budget (Wasserman, 1993). In the proposed article, a decision making algorithm is offered which is required in the designing phase to determine and choose the product's technical requirements.

The algorithm consists of two decision making techniques including ANP and BGP. The goal of ANP is to determine and evaluate the relationship between CNs and PTRs. ANP approach will facilitate the evaluation of interrelations between CNs and the correlation between PTRs. As the nature of product designing is somehow multi objective and it is also required to calculate the overall priorities in technical requirements through ANP, we should combine the results of ANP and the goal and criteria in product designing such as resource limitation, extendibility and manufacturability by a goal programming model; after minimizing all the digressions we should focus on the technical requirements and finally determine them. The relative scales for the above goals are being calculated by pair comparisons and experts' opinions in this matter. Finally, the required technical requirements are determined at the designing phase after solving the BGP model.

This article is presented in six sections. The second section describes the traditional QFD framework and House of Quality (HOQ) as are commonly discussed in quality management literature. The third section presents ANP fundamental and Sa'aty super matrix model. In the fourth section, decision algorithm and different phases of the proposed model are dealt with. The model is manipulated for designing a software product (software selection of Integrated Management Information System i.e. IMIS), in section five. Finally, last section talks about the results of the proposed model.

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A Review of Quality Function Deployment:

Quality function deployment was first introduced by Akao in 1966. It was developed at Kobe Shipyards of Mitsubishi Heavy Industries in 1972. In 1986 Ford Company became a pioneer in using QFD in designed vehicle parts in the United State. Now it is widely used in both Japan and the United States as an effective tool in designing new products (Carnevalli and Miguel, 2008; Erikkson and McFadden, 1993; Iranmanesh and Thomson, 2008; Matook and Indulska, 2009; Shilito, 1994). By using QFD, companies will be able to keep their competitive advantages through three strategies of decrease in costs, increase in income, and decrease in the time to market of the new goods and services (Hunt and Xavier, 2003; Khademi-Zare, *et al*., 2010). Establishment costs, shorter circulation in product's design, fewer customers' complains, documentation, determining critical points in the product's quality, recognizing risk factors in the early stages of designing are among the other advantages of QFD (Akoa, 1990; Biknel, 2001; Hun, *et al*., 2001). Further details on the benefits of using QFD can be found in (Carnevalli and Miguel, 2008; Griffin, 1992; Zarei, *et al*., 2011).

According to four matrices model of ASI (American Supplier Institute), QFD is a process composed of structured matrixes, based on the following goals:

a. Translating the customer's needs to designing or engineering requirements;
b. Transforming important designing requirements to the parts specifications;
c. Transforming important parts specifications to manufacturing and production operations;
d. Transforming important manufacturing and production operations to special operations and their control.

The above mentioned four make a series and the output of each will make the input of the next level. Researches show that less than 5% of the companies are successful in continuing the process beyond the HOQ (Cox, 1992). Many of QFD benefits are resulted from HOQ. This article also puts its emphasis on this matrix.

House Of Quality (HOQ):

The first phase of QFD, usually called house of quality (HOQ), is of strategic importance, since it is in this phase that the customer's needs are identified and then, incorporating the producing company's competitive priorities, converted into appropriate technical measures to fulfill the needs. HOQ is a kind of process map which brings about the possibility of relationship between the parts (Carnevalli and Miguel, 2008; Karask, *et al*., 2002). Since it is so widespread with a variety of contents, has become the final point in many real QFD projects. The different phases in the creation of HOQ are as the followings:

a. Recognizing the CNs;
b. Determining the PTRs;
c. Determining the relative importance of CNs;
d. Determining the relationship between the CNs and PTRs;
f. Determining the correlation between the CNs;
g. Determining the correlation between the PTRs;
h. Determining the overall priorities in PTRs and other general goals in designing the product (see Fig. 1). The reader interested in details of QFD and corresponding calculations is referred to (Griffin and Hauser, 1993; Hauser and Clausing, 1998; Kohen, 1995; Karsak, *et al*., 2002; Matook and Indulska, 2009; Shlito, 1994).

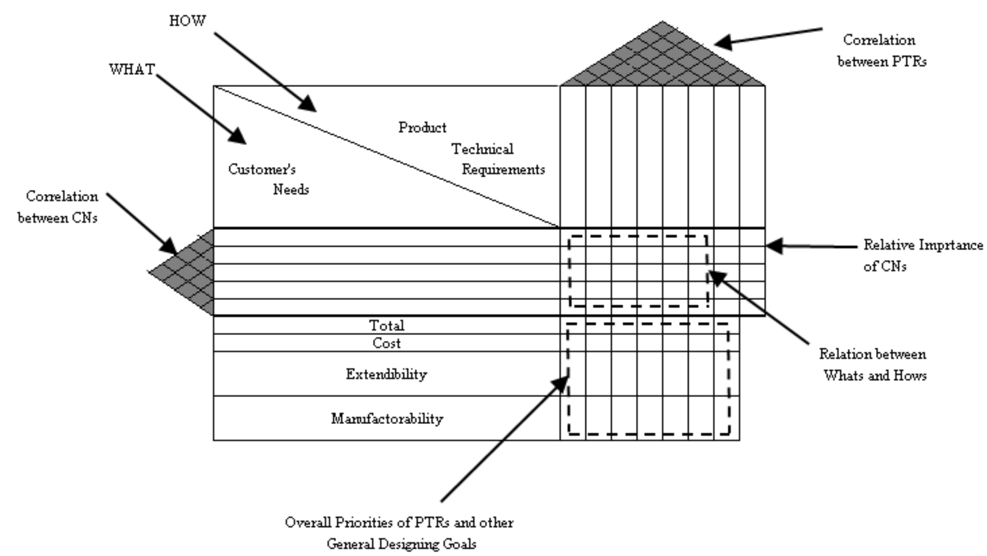


Fig. 1: Schematic of a House of Quality.

ANP :

ANP is a multi criteria technique which was introduced by (Sa'aty, 1970) and divides the problem of decision making into different levels which all together form a kind of hierarchy. ANP has the ability to be used as an effective tool in the interactions between the elements of network structure (Carlucci and Schiuma, 2009; Ergu, *et al*., 2011; Karsak, *et al*., 2002; Lee and Kim, 2000; Sa'aty, 1999). Fig. 2 shows a network system with feedback, inner and outer dependency. In the system there are two-way arcs, within the same level and among levels. Arc from component C4 to C2 indicates the outer dependence of the elements in C2 on the elements in C4 with respect to a common property. Loop in a component indicates inner dependence of the elements in that component with respect to a common property (Carlucci and Schiuma, 2009)

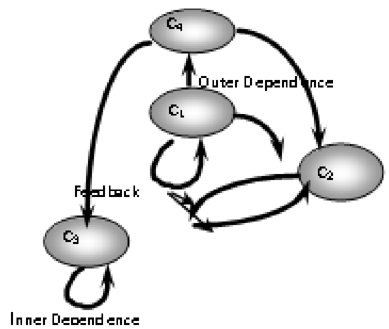


Fig. 2: Feedback Network with clusters having inner and outer dependence among their elements.(Carlucci, 2009)

Fig. 3 presents a sample of ANP. The symbol ( ) in the related square reveals the relationship between minor goals. Generally speaking, ANP consists of two stages: First is the formation of the network and second is the factors' priority calculation. In order to form the structure of the problem, all the interactions should be considered. All of these relations and the correlation are evaluated by using super matrix and pair wise comparisons. Super matrix is the same matrix resulted from the relations between the network elements and the priority vectors in these relations (Sa'aty, 1999). A super matrix for a three-phase hierarchy is as the followings:

In this super matrix W_{21} is a vector showing the effect of the goal on each criterion. W_{32} shows the effect of each criterion on the alternatives. The above mentioned super matrix is formed to reduce the amount of calculations for determining general priorities. This will reveal the total effect of each factor on the other factor in their interaction (Sa'aty, 1999). If a network contains only two groups (clusters) of criteria and solutions, then for calculating the correlation of the system element you can use Sa'aty or Takizava's views presented in 1986 (Karsak, *et al*., 2002) which is the same method used in this paper.

Model Construction:

Designing the model in the proposed paper is for recognizing and choosing the product's requirements which are required to be considered in the designing process based on the goals and restrictions. This decision algorithm is divided into two main phases; the firs phase includes the formation of HOQ matrix with the ANP approach and the second one is the combination of the first phase results with goal programming model for determining the product's technical requirements needed to be taken into consideration by designing team.

One of the goals of decision algorithm is the possibility of modeling and determining the relations between factors inside HOQ matrix. There are some other factors such as resources restrictions, extendibility and manufacturability which are important in the analysis. Extendibility means how much of this improvement in technical requirements can be transferred to other technical requirements. Manufacturability shows the problems in creating or changing a technical requirement or the efforts for the desired improvements. For example, in order to improve a technical requirement one may need a special technology, while the other would easily be improved. Restrictions in resources are known according to software's technical specifications and the technical specifications priority based on the goals such as extendibility and production capability. Then these priorities are modified and are calculated for determining the correlations in HOQ based on the goals. The relative scales for the desired goals are determined by pair wise comparisons. Finally all of the achieved information is combined with a BGP model for determining technical specifications in designing process. Fig.4 shows this algorithm step by step.

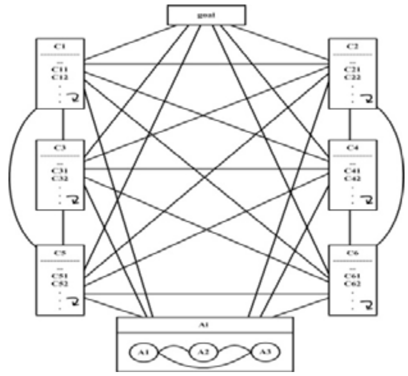


Fig. 3: A sample of ANP.

Since goal programming with limited and balanced equivalents can consider multiple objectives with their relative importance and minimize the overall deviation from these goals, therefore it is preferable to use this kind of programming in this research as a decision making tool. This special feature can pave the way to enter some goals including restriction in resources, extendibility and manufacturability in the product's designing process. Goal programming minimizes the overall balance deviation from the mentioned goals and studies them at the same time. The scales are not ranked but can reflect the decision maker's priorities according to the relative importance of each goal. Lack of balance in scales, happening in BGP during measuring goals with different units, is solved by normalization (Schniederjans & Garvin, 1997). The super matrix showing QFD model in this article is as followings:

Step1. Recognizing CN and their related TR

Step2.Studying the correlations and relations in HOQ and determining TRs overall priorities by ANP

Step 3. Recognizing measurement criteria and the resources restrictions

Step 4. Determining TRs' preferences based on the designing goals

Step 5. Modifying restrictions in resources and other designing goals

Step6. Calculating the relative weights of desired goals by pair wise comparisons

Step7. Formulating BGP model and solving it in order to determining the TRs of designing phase

Fig. 4: Step by step process of the proposed decision algorithm.

W_1 shows the effects of the goal on customer's needs; in other words it shows the importance of CNs. W_2 is a matrix showing the effect of customer's needs on each technical requirement. W_3 is the matrix showing the interrelations in CNs and W_4 is the matrix showing interrelations in PTRs. QFD model network is shown in Fig.5. According to the above abbreviations, the interrelations of CNs (W_3) multiplied by the relative importance of CNs (W_1) equals to the priorities of the CNs correlation. Exactly the same as what was mentioned above, the interrelation of the PTRs (W_4) multiplied by the relationship of CNs with each of the PTRs (W_2) equals to priories of TRs correlation. After calculating W_{CNs} and W_{PTRs}, the general priorities for technical requirements shown by W_{ANP}, are calculated as the followings:

$W_{CNs}=W_1 * W_3 \quad W_{PTRs}=W_2 * W_4 \quad W_{ANP}=W_{PTRs} * W_{CNs}$

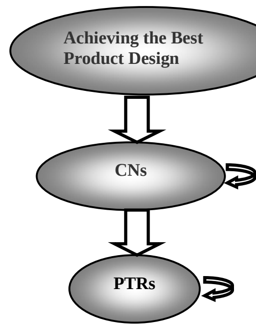


Fig. 5: Network model of QFD.

Based on a group of technical requirements which should be taken into consideration in designing phase, a BGP model is made with the first levels' results. This model is also related to the goals which we should focus on during the designing period including restrictions in resources, extendibility, and manufacturability. The goals related to the resources restrictions are easily formulated. But other goals such as extendibility and manufacturability will result in preferential scales for the technical requirements. In order to formulize these goals in the model, we need to determine a preferential rate for each requirement and then the negative derivations of these goals from one, are applied in the goal function.

Goal programming model with limited variations:

In order to meet the organization and customer goals and restrictions simultaneously, we are using bounded goal programming in this article. The general form of this model in design making algorithm is as the followings:

$$MinZ = \sum_{i=1}^{m} W_i \left(d_i^+ - d_i^-\right)$$

$$s.t.$$

$$\sum_{j=1}^{n} W_j X_j + \left(d_1^+ - d_1^-\right) = 1$$

$$\sum_{j=1}^{n} r_{ij} X_j + \left(d_i^+ - d_i^-\right) = R_i \qquad i = 2,3,\ldots,m$$

$$\sum_{j=1}^{n} W_{ij} X_j + \left(d_i^+ - d_i^-\right) = 1 \qquad i = 2,3,\ldots,m$$

$$0 \le X_j \le 1 \qquad j = 1,2,\ldots,n$$

$$0 \le \left(d_i^+, d_i^-\right) \le 1 \qquad i = 1,2,\ldots,m$$

W_i is the goals weight in the balanced goal model. d_i^+ and d_i^- shows the variables of positive and negative deviations in the ith goal. x_j, limited variable between zero and one, shows the jth PTR. W_j shows the relation priority of the jth PTR. r_{ij} is a pat of the ith sources used by the jth PTR. R_i shows resource restriction in ith resource, and w_{ij} is the ith relative importance in PTRs based on the ith goal or criterion.

Model Employment:

In this section the decision algorithm and the model making process will be discussed based on a case study on the software of the comprehensive system in management data.The pair wise comparison tables and some relative matrixes are not mentioned here and we just put the matrix results. The results of pair wise comparisons used here, are all the outcome of the experts and managers opinions in QFD team which are taken to manipulate the model in the software company. In fact, QFD team is the statistical group of decision making.

Step 1:

In our case study, 6 CNs were determined including data security, reliability, accessibility, speed, proper reaction toward users' mistakes and the possibility of removing the difficulty. After determining the CNs, by the help of system designers, software experts and the existing standards for software quality including CMM (Capability Maturity Model) and ISO-9126, ten PTRs were determined for the software, including the average interval between defects (X_1), the average time for repair (X_2), the rejection amount of inconsistent data (X_3), accessibility of shared data (X_4), the average time for data retrieval (X_5), the possibility of taking backup files (X_6), program access and control level (X_7), the security level of data accessibility (X_8), the average time of data changing (X_9), executing exe files (X_{10}).

Step 2:

In this step we determine the interrelations between CNs and PTRs through the previous step data and the interviews done with experts and the technical criteria. This step can be divided into 4 parts:

Determining the relative importance of CNs:

Suppose that there is independency between CNs, so in order to determine their importance we can ask this question "Which customer's needs are more important?" the normalized matrix out of the group opinion i.e. W_1 is as the following:

$$W_1 = \begin{array}{c} CN_1 \\ CN_2 \\ CN_3 \\ CN_4 \\ CN_5 \\ CN_6 \end{array} \begin{pmatrix} 0.186 \\ 0.190 \\ 0.161 \\ 0.157 \\ 0.136 \\ 0.169 \end{pmatrix}$$

Determining the relationship between CNs and PTRs:

In order to determine the relation between the CN "input security" and PTRs, we should ask this question "According to the customer's need, which technical requirement is more important, the rejection amount of incompatible data or the possibility of taking back up files?"; If we do the same thing about the other needs and requirements, the final matrix showing the relative scales for the software technical requirements in accordance to each customer's needs (W_2) will be as the followings:

$$W_2 = \begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{array}{c} \begin{array}{cccccc} CN_1 & CN_2 & CN_3 & CN_4 & CN_5 & CN_6 \end{array} \\ \begin{pmatrix} 0 & 0.578 & 0 & 0 & 0 & 0.126 \\ 0.444 & 0.213 & 0 & 0 & 1 & 0 \\ 0 & 0.198 & 0 & 0 & 0 & 0.874 \\ 0 & 0 & 0.056 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.71 & 0 & 0 \\ 0.0805 & 0 & 0 & 0 & 0 & 0 \\ 0.3047 & 0 & 0.651 & 0 & 0 & 0 \\ 0.5704 & 0 & 0.241 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.065 & 0 & 0 \\ 0 & 0 & 0.225 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

Calculating the inner dependence (correlation) of the customer's needs :

Based on the relations between CNs, illustrated in Fig.6, the effect of each need on others is calculated through pair wise comparisons. For example you can ask this question "based on the data security that is supposed as the major CN, how much is the importance of other CNs?"; so the major CN weight would equal to one, those of unrelated CNs with data security would equal to zero and the rest CNs' weights would be between one and zero regarding to their correlation with data security. The group judgment results and the normalized vector of data security importance comparing to other CNs is cited in Table1.

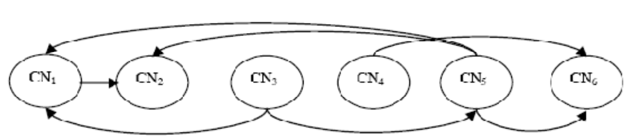


Fig. 6: Correlation between CNs.

Table 1: CNs priorities and weights.

CN	CN Priority	CN Weight
CN_1	1	0.743
CN_2	0	0
CN_3	0.258	0.192
CN_4	0	0
CN_5	0.087	0.065
CN_6	0	0
Sum	1.345	1

Table 2: Required man-hour for each PTR (hr)

PTR	Man-Hour
X_1	930
X_2	570
X_3	880
X_4	530
X_5	670
X_6	320
X_7	990
X_8	1040
X_9	860
X_{10}	1250

In case that we follow the same procedure for the other needs, the kind of matrix showing the correlation between CNs (W_3) is as the following:

$$W_3 = \begin{array}{c} \\ CN_1 \\ CN_2 \\ CN_3 \\ CN_4 \\ CN_5 \\ CN_6 \end{array} \begin{array}{c} \begin{array}{cccccc} CN_1 & CN_2 & CN_3 & CN_4 & CN_5 & CN_6 \end{array} \\ \begin{bmatrix} 0.743 & 0.238 & 0 & 0 & 0 & 0 \\ 0 & 0.687 & 0 & 0 & 0 & 0 \\ 0.192 & 0 & 1 & 0 & 0.103 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0.056 \\ 0.064 & 0.075 & 0 & 0 & 0.897 & 0.246 \\ 0 & 0 & 0 & 0 & 0 & 0.698 \end{bmatrix} \end{array}$$

Calculating the correlation of the software Technical Requirements:

In order to calculate this correlation, the network structure illustrated in Fig.7 is used. The correlation matrix between PTRs (W_4) is as the following:

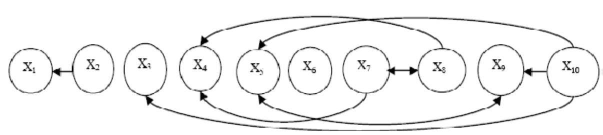


Fig. 7: Correlation between PTRs.

$$W_4 = \begin{array}{c} \\ x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \\ x_{10} \end{array} \begin{array}{c} \begin{array}{cccccccccc} x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 & x_8 & x_9 & x_{10} \end{array} \\ \begin{pmatrix} 0.172 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.828 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.877 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.674 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.171 & 0 & 0 & 0 & 0.069 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.094 & 0 & 0 & 0.837 & 0.126 & 0 & 0 \\ 0 & 0 & 0 & 0.232 & 0 & 0 & 0.163 & 0.874 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.75 & 0 & 0 & 0 & 0.719 & 0 \\ 0 & 0 & 0 & 0 & 0.079 & 0 & 0 & 0 & 0.212 & 1 \end{pmatrix} \end{array}$$

The overall relative weights of CNs based on the correlations i.e. WCNs, are as the following:

$$W_{CNs} = W_3 \times W_1 = \begin{array}{c} CN_1 \\ CN_2 \\ CN_3 \\ CN_4 \\ CN_5 \\ CN_6 \end{array} \begin{pmatrix} 0.183 \\ 0.130 \\ 0.211 \\ 0.166 \\ 0.190 \\ 0.118 \end{pmatrix}$$

The relative weights of PTRs based on the correlations i.e. W_{PTRs} , are as the followings:

$$W_{PTRs} = W_4 \times W_2 = \begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{array}{c} \begin{array}{cccccc} CN_1 & CN_2 & CN_3 & CN_4 & CN_5 & CN_6 \end{array} \\ \begin{pmatrix} 0 & 0.1009 & 0 & 0 & 0 & 0.0217 \\ 0.444 & 0.7011 & 0 & 0 & 1 & 0.1043 \\ 0 & 0.1737 & 0 & 0 & 0 & 0.7665 \\ 0 & 0 & 0.0395 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.1259 & 0 & 0 \\ 0.0805 & 0 & 0 & 0 & 0 & 0 \\ 0.3269 & 0 & 0.5899 & 0 & 0 & 0 \\ 0.5482 & 0 & 0.3595 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.5792 & 0 & 0 \\ 0 & 0.0244 & 0 & 0.2949 & 0 & 0.1075 \end{pmatrix} \end{array}$$

Finally, the overall relative weights of PTRs (W_{PTRs}) based on the overall relative weights of CNs (W_{CNs}) i.e. W_{ANP} which reflect the overall relations inside HOQ (Fig.7), are as the following:

$$W_{ANP} = W_{PTRs} \times W_{CNs} = \begin{array}{c} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{bmatrix} 0.0157 \\ 0.3020 \\ 0.1131 \\ 0.0088 \\ 0.0210 \\ 0.0149 \\ 0.1828 \\ 0.1705 \\ 0.0969 \\ 0.0669 \end{bmatrix}$$

The results of ANP analysis show that the most important requirement in software designing for IMIS is the rejection of inconsistent data (X_3) with the relative weights of 0.3020. On the second priority, there is the program access and control level (X_7), with the relative weights of 0.1828.

Step 3:

In this step the criteria related to the restriction of resources come into the decision making process. The estimated man-hour required to create or correct any of PTRs is according to Table 2. On the other hand, the total required man-hour that the company can allocate for software update or development was 6500 man-hour based on the number of experts and their working hours.

Step 4:

There are other goals, regardless of budget and the workforce, in software designing including extendibility and manufacturability of PTRs, which are determined on a five-level scale from very low to very high. If the results are normalized, we will have W_M and W_E matrixes as bellows:

$$W_M = \begin{array}{c} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{pmatrix} 0.098 \\ 0.110 \\ 0.098 \\ 0.115 \\ 0.083 \\ 0.113 \\ 0.105 \\ 0.098 \\ 0.088 \\ 0.091 \end{pmatrix} \quad , \quad W_E = \begin{array}{c} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{pmatrix} 0.095 \\ 0.102 \\ 0.109 \\ 0.104 \\ 0.102 \\ 0.088 \\ 0.093 \\ 0.111 \\ 0.095 \\ 0.100 \end{pmatrix}$$

Step 5:

The vectors related to resources restrictions, extendibility and manufacturability should reflect the correlations and interrelations in the software's technical requirements.

h': The adjusted vector for the required man-hourof PTRs.
W_E': The adjusted vector for PTRs' extendibility.
W_M': The adjusted vector for PTRs' manufacturability.

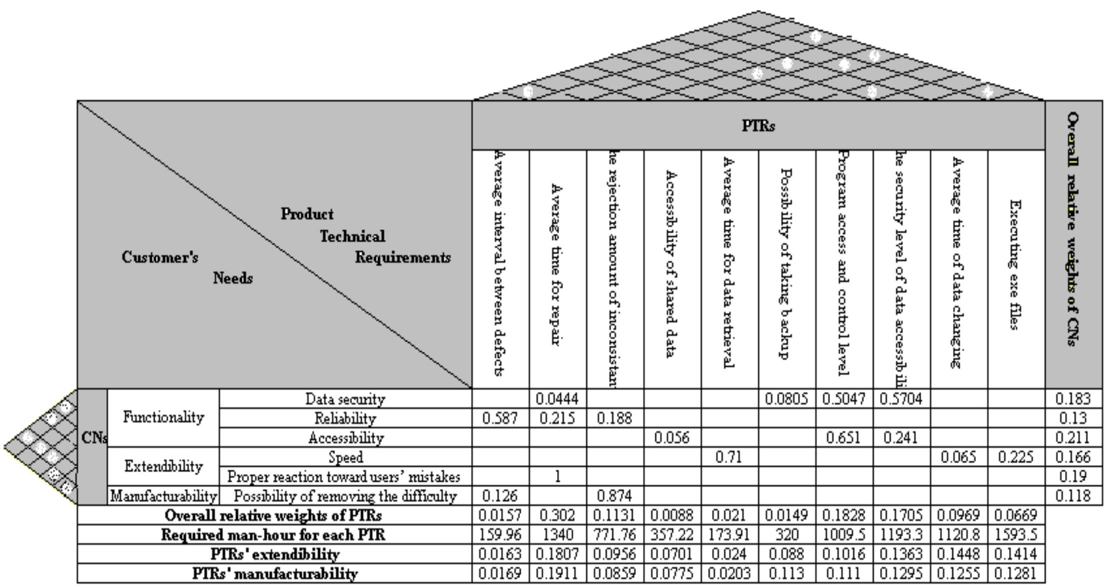
$$\mathrm{W_E}' = W_4 \times W_E = \begin{array}{c} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{bmatrix} 0.0163 \\ 0.1807 \\ 0.0956 \\ 0.0701 \\ 0.0240 \\ 0.0880 \\ 0.1016 \\ 0.1363 \\ 0.1448 \\ 0.1414 \end{bmatrix} \quad \mathrm{h}' = W_4 \times h = \begin{array}{c} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{bmatrix} 159.96 \\ 1340.04 \\ 771.76 \\ 357.22 \\ 173.91 \\ 320.00 \\ 1009.49 \\ 1193.29 \\ 1120.84 \\ 1593.49 \end{bmatrix} \quad \mathrm{W_M}' = W_4 \times W_M = \begin{array}{c} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \\ X_{10} \end{array} \begin{bmatrix} 0.0169 \\ 0.1911 \\ 0.0859 \\ 0.0775 \\ 0.0203 \\ 0.1130 \\ 0.1110 \\ 0.1295 \\ 0.1255 \\ 0.1281 \end{bmatrix}$$

Now with all the achieved data, we are able to build the HOQ. Fig.8 shows the HOQ related to the process.

Step 6:

In designing a software or any other product, there are always some goals and criteria at the same time. The goals and criteria studied in this paper in designing the software are: focusing on the interrelations between each group of factors with ANP, the available workforce, extendibility and manufacturability. In order to measure the relative weights of these criteria by pair wise comparisons we are in need of expert views which have been normalized as the followings (W_j):

$$W_j = \begin{bmatrix} 0.613 \\ 0.045 \\ 0.094 \\ 0.248 \end{bmatrix} \begin{array}{l} \Rightarrow \quad ANP \\ \Rightarrow \quad \text{Workforce} \\ \Rightarrow \quad \text{Extensibility} \\ \Rightarrow \quad \text{Manufacturability} \end{array}$$



Customer's Needs / Product Technical Requirements			Average interval between defects	Average time for repair	The rejection amount of inconsistant	Accessibility of shared data	Average time for data retrieval	Possibility of taking backup	Program access and control level	The security level of data accessibili	Average time of data changing	Executing exe files	Overall relative weights of CNs
CNs	Functionality	Data security		0.0444				0.0805	0.5047	0.5704			0.183
		Reliability	0.587	0.215	0.188								0.13
		Accessibility				0.056			0.651	0.241			0.211
	Extendibility	Speed					0.71				0.065	0.225	0.166
		Proper reaction toward users' mistakes		1									0.19
	Manufacturability	Possibility of removing the difficulty	0.126		0.874								0.118
Overall relative weights of PTRs			0.0157	0.302	0.1131	0.0088	0.021	0.0149	0.1828	0.1705	0.0969	0.0669	
Required man-hour for each PTR			159.96	1340	771.76	357.22	173.91	320	1009.5	1193.3	1120.8	1593.5	
PTRs' extendibility			0.0163	0.1807	0.0956	0.0701	0.024	0.088	0.1016	0.1363	0.1448	0.1414	
PTRs' manufacturability			0.0169	0.1911	0.0859	0.0775	0.0203	0.113	0.111	0.1295	0.1255	0.1281	

Fig. 8: The HOQ resulted from step 1 to 5.

Step 7:

We can build the goal programming model with the balanced bounded variables, required in determining the software's TRs during designing level, by applying our completed HOQ (Fig.8), the relative weights of the designing goals and criteria (W_j) and BGP. X_1, X_2,…, X_{10}, show decision making variables or the software's TRs in BGP model. The first restriction is related to the overall priorities of PTRs. The third is the average amount of extendibility, and the forth is related to manufacturability of the software's TRs. The right hand side of the second constraint indicates the available man-hour. The right hand side of the first, third and forth constraints are related to lateral scales and priorities of TRs, which are at most equal to one. The objective function is to minimize the positive and negative deviations from the desired value.

$$\text{Min}Z = 0.613(d_1^+ - d_1^-) + 0.045(d_2^+ - d_2^-) + 0.094(d_3^+ - d_3^-) + 0.284(d_4^+ - d_4^-)$$

s.t.

$$(1)\begin{cases}0.0157X_1 + 0.3017X_2 + 0.113X_3 + 0.0080X_4 + 0.0210X_5 + 0.0148X_6 \\ +0.1823X_7 + 0.1700X_8 + 0.0964X_9 + 0.0648X_{10} + d_1^+ - d_1^- = 1\end{cases}$$

$$(2)\begin{cases}0.1599X_1 + 1.3400X_2 + 0.7717X_3 + 0.35722X_4 + 0.17391X_5 + 0.320X_6 \\ +1.00949X_7 + 1.19329X_8 + 1.12084X_9 + 1.59349X_{10} + d_2^+ - d_2^- = 1\end{cases}$$

$$(3)\begin{cases}0.0163X_1 + 0.1807X_2 + 0.0956X_3 + 0.0710X_4 + 0.0240X_5 + 0.0880X_6 \\ +0.1016X_7 + 0.1363X_8 + 0.1448X_9 + 0.1414X_{10} + d_3^+ - d_3^- = 1\end{cases}$$

$$(4)\begin{cases}0.0169X_1 + 0.1911X_2 + 0.0859X_3 + 0.0775X_4 + 0.02030X_5 + 0.1130X_6 \\ +0.1110X_7 + 0.1295X_8 + 0.1250X_9 + 0.1281X_{10} + d_4^+ - d_4^- = 1\end{cases}$$

$$0 \le X_j \le 1 \qquad j = 1, 2, \ldots, 10$$

$$0 \le \left(d_i^+, d_i^-\right) \le 1 \quad i = 1, 2, 3, 4$$

After solving BGP model by Lingo software, the following results are derived:

$$X_1 = X_2 = X_3 = X_6 = X_7 = X_8 = 1$$
$$X_4 = X_5 = X_9 = 0.95$$
$$X_7 = 0.8$$
$$d_1^- = 0.075 \qquad d_2^- = 0.058 \qquad d_3^- = 0.131 \qquad d_4^- = 0.128$$
$$d_1^+ = d_2^+ = d_3^+ = d_4^+ = 0$$

As can be seen, X_1, X_2, X_3, X_6, X_7 and X_8 are equal to 1, while X_4, X_5 and X_9 are equal to 0.95 and X_{10} is equal to 0.8. It means that the software's TRs such as "breakdown average time", "the average time in repairs", "the amount of rejecting inconsistent data" and "the possibility of taking a backup file" are all chosen for full securing. But other requirements including "shared data availability" "the average time in data retrieval" "the average time in changing data" and " the time needed in opening a file" are all chosen for partial security. The amounts of d_1, d_2, d_3, and d_4 show undesirable deviations from goals and ANP criteria. This kind of deviation from the desired solution is due to inconsistency and contradictions in organizational and customer goals.

Conclusion:

As all other tools, the advantages and effectiveness of QFD depend on how it is being manipulated. In order to make it more effective, in the proposed paper, a kind of systematic approach of decision making was introduced in designing process of the product in QFD. This decision algorithm facilitates the study of the relations between customer's needs, technical requirements, correlations between them, applying resource restrictions and also other criteria including extendibility and manufacturability. In this era of increasing competitiveness, we should meet the interactions between different ideas and use them to reach a combined model in QFD. Therefore, the potentials of QFD as an effective tool will become more actual and possible. In this respect, this paper has tried to apply the combined model of ANP and BPG for interfering customer's needs and product's technical requirements in product designing by QFD. The correlation of different elements in QFD based on ANP was applied in the decision algorithm. According to the restrictions in resources and the multi-objectivity of the problem, a BPG model was made in order to determine the technical requirements and the product's controlling points for customer's satisfaction. We should bear in mind that QFD alone can not be a tool for optimum designing; the priorities resulted from ANP, restrictions in resources and other criteria in designing such as extendibility and manufacturability in BGP model give more justifiable answers. Also, the designing necessities are determined in a way that maximizes customer's satisfaction based on the existing restrictions.

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