An effective decision-making method using a combined QFD and ANP approach

YU-TING LEE*, WEI-WEN WU*, GWO-HSHIUNG TZENG**
*Department of International Trade,
Ta Hwa Institute of Technology,
1 Ta Hwa Road, Chiung-Lin, Hsin-Chu 307,
Taiwan
*miketina@ms5.hinet.net
*itmike@thit.edu.tw

**Distinguished chair Professor G.-H. Tzeng,
Natinal Chiao Tung University, Institute of Management of Technology,
1001 Ta-Hsueh Road, Hsinchu 300, Taiwan.
**Department of Business Administration, Kai Nan University,
No.1 Kainan Rd, Shinshing Tsuen, Luchu Shiang, Taoyuan 338,
Taiwan.
**ghtzeng@cc.nctu.edu.tw

Abstract: - Quality function deployment (QFD) is a valuable method that provides a means of translating customer needs into the appropriate technical requirements for each stage of detailed operations in product development and production. During the QFD implement process, the Analytic Hierarchy Process (AHP) has been used to determine the relative importance weights between criteria or the relationship between the row and column variables of each matrix. However, the AHP has the limit with its independence assumptions, which is a special case of the Analytic Network Process (ANP). The ANP is a mu1tiple criteria decision-making (MCDM) method used to derive relative priority from individual judgments, which can deal with all kinds of dependences systematically. Thus, the purpose of this paper is to develop an effective decision-making method based on QFD and ANP approach to help for making better decisions of planning or evaluation problems. Also, an empirical example is presented to illustrate the application of the proposed method.

Key-Words: - Quality function deployment, Analytic Hierarchy Process, Analytic Network Process, mu1tiple criteria decision-making

1 Introduction

To chase continuous improvement for enriching global competitiveness, most companies are striving to seize customer needs and to seek for higher levels of quality for their products and services [37][18][9]. To fulfill these demands, Quality Function Deployment (QFD) provides profitable solutions with the emphasis on goal-oriented, fast, flexible and customer-focused approach [14]. The aim of QFD is to build in the customer satisfaction at the product design phase, which is attracting a lot of attention in several industries. The QFD is increasingly being recognized as an excellent means of ensuring that the "Voice of the Customer" directs each stage of product development and production process, as well as to integrate all the efforts of the organization into getting a favorable solution [5]. This way usually results in providing better products and services which reflect more accurately customer needs [24]. As companies turn to stress the importance of customer satisfaction, QFD is being rapidly adopted as a means of products and services planning to meet the customer requirements [23].

The QFD was originally offered to collect and analyze the voice of the customer for improving products or developing new products with higher quality to meet or surpass customer's needs [7]. Now it has been extended to apply for any kind of planning process when a cross-functional team wants to systematically prioritize their possible solutions [5][11]. During the QFD implement process, the Analytic Hierarchy Process (AHP) has been used to determine the relative importance weights between criteria or the intensity of the relationship between the row and column variables of each matrix [20][27][8][4]. However, the AHP with its independence assumptions on upper levels from lower levels and the independence of the elements within a level [34]. Like many traditional mu1tiple criteria decision-making (MCDM) methods, the AHP is based on the independence assumption, but each individual criterion is not always completely independent [36][21]. For solving the interactions among elements, the ANP (Analytic Network Process) as a new MCDM method was proposed by [33]. The ANP is the mathematical theory that can deal with all kinds of dependences systematically [30]. Since the ANP has these advantages, in this paper, we employ a combined QFD and ANP approach to develop an effective decision-making method to help for making better decisions of planning or evaluation problems. Also, an empirical example is presented to illustrate the procedure of our proposed method and to demonstrate its usefulness and validity.

The rest of this paper is organized as follows. In section 2, some of the prior literature and definitions related to the QFD and ANP are reviewed. In section 3, the proposed method is developed. In section 4, an empirical example is illustrated. Finally, based upon the findings of this research, conclusions and suggestions are presented.

2 Quality Function Deployment and Analytic Network Process

Both QFD and ANP are the comprehensive decision-making method that provides a means of coping with complex MCDM matters. The QFD is an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production [6]. The ANP is a MCDM method used to derive relative priority from individual judgments, which can deal with all kinds of interactions systematically [34]. Especially, the QFD is advantageous for making planning [15], whereas the ANP is good for evaluating alternatives [27]. The essentials of the QFD and ANP are discussed as follows.

2.1 Quality Function Deployment

As an effort to develop a quality assurance method in order to consider quality and customer satisfaction early into a production process, the initial concept of QFD was mainly conceived by Akao in Japan in the late 1960s [1][3]. A few years later in 1972, QFD was further developed at the Kobe shipyards of Mitsubishi Heavy Industries Ltd. From then on, QFD applications became popular and were promoted successfully among many Japanese companies such as Toyota, Komatsu, Matsushita, and NEC in industries far ranging from manufactured and assembled products, construction, chemical process, service, and software [1]. Because of using QFD well in Japanese companies, the West started to introduce QFD from 1983, and then it has played an important role at companies such as General Motors, Chrysler, Digital Equipment, Hewlett-Packard, and AT&T. Today, the QFD continues to inspire strong interest around the world and is employed as a valuable method for numerous companies in many countries to enhance their competitiveness through rapid product development time, better quality, lower cost, and higher customer satisfaction.

The QFD is an integrated planning method that can assure and improve the alignment of elements of design processes with the requirements of customers, as well as it is a managerial philosophy that can help enhance the organizational and managing effects [40]. Especially, QFD employs a cross-functional team to plan and design new or improved products or services through a structured and well-documented framework [18][9][25]. In contrast with traditional requirements of engineering methodologies, benefits of using QFD are such as: carries the voice of the customer into the process; abolishes waste and creates flexibility; supports customer-oriented decisions of design; determines objectives and creates focus on the essential; takes interests of various groups into account; systematizes communication and provides for continuity and responsiveness; creates transparency and makes coordination processes easier; and speeds up development process [14].

According to the results of a large research of literature review [7], it indicates that functional fields of QFD are extensively wide such as customer needs analysis, product development, quality management, product design, planning, decision-making, engineering, management, teamwork, timing, and costing. Moreover, QFD has been applied in various industries such as transportation, communication, electronics, electrical utilities, software systems, manufacturing, services, education, and research. It has been successfully applied in many companies as a powerful tool that addresses strategic and operational decisions in businesses [7]. Additionally, Japanese Standards Association (JSA) provides various exercise manuals of QFD, such as for Quality Deployment in The Most General Model, for New Product Development, for Product Liability, for ISO9000 Series, for Process Assurance from Designing Stage, for Service, for Parts Suppliers, for Material

Manufacturers, for Processing Equipment Manufacturers, for Quality Function Deployment in Narrow Sense, for Reliability Deployment, for Technology Deployment, and for Policy Deployment [17]. Hence, the QFD can be used for not only product or service development, but also customer satisfaction, project selection, process management, strategic planning, and general decision making.

There are several approaches have been developed for QFD. The Four-Phase approach of American Supplier Institute (ASI) is the most common one [5][29]. For example, the Four-Phase approach translates the customer voice into product characteristics in the first phase, then deploys the product characteristics into part characteristics, next transforms the part characteristics into process characteristics, and finally converts the process characteristics into production characteristics. Therefore, this approach comprises four matrices consisting of the planning matrix of product planning phase, the design matrix of component deployment phase, the operational matrix of process planning phase, and the control matrix of production planning phase. The primary logic of QFD is to systematically take the customer needs down to the level of detailed operations, in which the key tool of QFD is the "House of Quality" (HOQ) [18][11][39]. We may consider that QFD is a comprehensives strategic planning method through several translations with serial interactive matrices of HOQ, which identifies and translates the WHATs into the HOWs. In this planning framework of QFD, the HOQ is a kind of mechanism that creates conceptual map visually and facilitates cross-functional planning and communications [12]. In practice, QFD consists hierarchically of several HOQ [38] allowing us to use flexibly more or less than four matrices, that all depends on the case.

As the above, the essence of QFD is the employment of the two-dimension HOQ which converts the WHATs into the HOWs. From this perspective, there are seven elements of the HOQ [18] as shown in Figure 1. These seven elements include: (1) WHATs are the initial inputs for the HOQ, which are obtained from the information by business research and analysis; (2) HOWs denotes the means for WHATs; (3) Relationship Matrix implies relationships between WHATs and HOWs, which expresses how much each HOW affects each WHAT, where the relations can either be presented by numbers or symbols; (4) Correlation Matrix of WHATs indicates inner dependence among the WHATs, where each WHAT is not certainly independent; (5) Relative Importance of WHATs denotes relative weights of the WHATs, where each WHAT are usually assessed by using 5, 7 or 9 point scales; (6) Correlation Matrix of HOWs indicates inner dependence among the HOWs, where interactions may exist within the HOWs; and (7) Overall Priorities of HOWs denotes the synthesized importance of the HOWs.

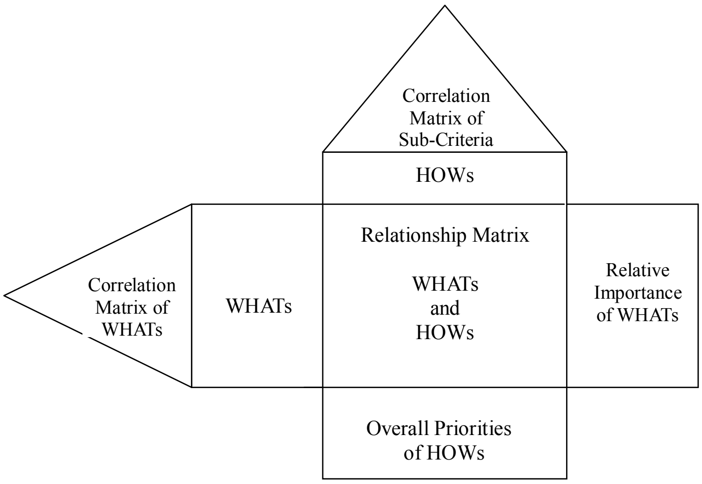

Figure 1. Seven elements of the HOQ.

2.2 Analytic Network Process

When we face the needs to make decisions with multi-criteria, it is useful to utilize MCDM method to solve this complex problem. There are many MCDM methods that have been developed such as ELECTRE, TOPSIS, AHP, etc., but these methods do not consider the interdependence among criteria and alternatives. For dealing with the interdependence among elements, the ANP as a new MCDM method was proposed by [33]. As [30] states, it allows one to include all the factors and criteria, tangible and intangible, that have bearing on making an optimum decision. Thus, the ANP is a multi-criteria approach for decision-making, and may transform qualitative judgments into quantitative values.

As is well-known, AHP is a beneficial method which is developed to cope with the problems in dealing with human intuitive judgment, when we apply multi-criteria and group decision-making with regard to a series of options. The AHP for decision-making was introduced first by [32]. For using the AHP, elements of a decision-making problem are organized into a multiple-level hierarchy. Then the AHP employs ratio scales to derive relative priorities for a set of elements by making paired comparisons. There are, however, some limitations of the AHP which need to be cleared up. Particularly important is that the AHP includes an assumption about the independence among elements under a hierarchical structure. To solve the independence assumption of the AHP, the ANP was developed by Saaty. Specifically, the ANP is a new theory that extends the AHP to deal with dependence in feedback, and utilizes the supermatrix approach.

Although both the AHP and the ANP derive ratio scale priorities by making paired comparisons, there are some differences between them [30]. The first difference is that the AHP is a special case of the ANP, because the ANP handles dependence within a cluster (inner dependence) and among different clusters (outer dependence). Secondly, the ANP is a nonlinear structure, while the AHP is hierarchical and linear with a goal at the top level and the alternatives in the bottom level [32]. Typically, The AHP model is a decision-making framework that assumes a unidirectional hierarchical relationship among decision levels. The top element of the hierarchical structure is the overall goal for the decision model. The hierarchy devolves to more specific attributes until a level of manageable decision criteria is met. By contrast, the ANP does not require this strictly hierarchical structure. Two-way arrows represent the interdependency between attribute levels, and within the same level, a looped arc is used. The directions of the arcs signify dependence, and arcs emanate from an attribute to other attributes that may influence it.

The ANP model may consist of a single network or a number of networks. [32] has demonstrated several types of ANP models, such as: the Hamburger Model, the Car Purchase BCR model, and the National Missile Defense model. According to the perspective of [19], the ANP may be differentiated into two kinds of models, namely, the Feedback System model and the Series System model. When the decision structure involves inner dependence among the elements, the Series System model can be expressed as the way that the goal controls a series of clusters with their own loops. As shown in Figure 2, this model starts with the goal and goes downstream to the criteria cluster, sub-criteria cluster, and alternatives cluster.

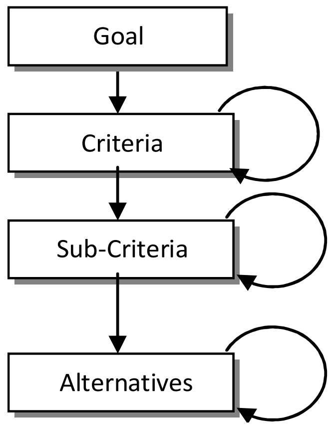

Figure 2. The Series System model

In order to utilize the ANP method, [31] suggested some principal points, such as: (1) think about the significant elements and decide what kind of logical groupings would best describe the problem; (2) build clusters and create the nodes within them; (3) examine and determine which element influences or is influenced by the others; (4) create the links between the parent node and its children nodes; and (5) make pairwise comparison judgments between elements and synthesize the overall priorities for the alternatives. In addition, [22] presented an analytical procedure for the ANP, including: (1) model construction and problem structuring; (2) pairwise comparison matrices of interdependent component levels; (3) supermatrix formation; and (4) selection of best alternatives. Hence, we have designed some steps for using the Series System model as follows.

STEP 1: Decision structure for evaluation

Decision making is the process of defining the decision goals, gathering relevant information and evaluation criteria, generating the broadest possible range of alternatives, evaluating the alternatives for advantages and disadvantages, selecting the optimal alternative, and monitoring the results to ensure that the decision goals are achieved [13][26]. Thus, the first step is to identify the decision goal and to develop a decision structure like the one that is shown in Figure 2. In the decision structure, there are three clusters (criteria cluster, sub-criteria cluster, and alternatives cluster) under the goal.

STEP 2: Pairwise comparisons

The arrow line connecting the goal to the criteria cluster mean that the criteria must be pairwise compared for their importance with respect to the goal. Similarly, the system of arrow lines connecting the criteria cluster to the sub-criteria cluster means the sub-criteria are pairwise compared with regard to which is more acceptable for that criteria. Similarly, the arrow line connecting the sub-criteria cluster to the alternatives cluster means that the alternatives must be pairwise compared for their preference with respect to the sub-criteria. For determining the relative importance between elements, decision makers are asked to respond through a series of pairwise comparisons. These pairwise comparisons are based on Saaty's nine-point scale and represent how many times one element is more important than another, where a score of 1 indicates equal importance between the two elements and 9 represents the extreme importance of one element compared to the other one. The or as ratio scale priorities by making paired comparisons of elements, where denotes the importance of the th element compared to the th element.

STEP 3: Supermatrix formation and calculation
For evaluating the weights of elements, the AHP uses the principal eigenvector of comparison matrix, while the ANP employs the limiting process method of the powers of the supermatrix [35]. A supermatrix is a partitioned matrix, where each submatrix is composed of a set of relationships between two clusters. The unweighted supermatrix (Figure 3) contains the local priorities derived from the pairwise comparisons throughout the Series System model. Where is a matrix that represents the weights of criteria with respect to the goal, the matrix that denotes the weights of sub-criteria with respect to criteria, and the matrix that shows the weights of alternatives with respect to sub-criteria. Moreover, these matrices , , and are denoted respectively as the inner dependence matrix of criteria, sub-criteria, and alternatives. To derive the overall priorities of elements, we need to multiply submatrixes numerous times in turn, until the columns stabilize and become identical in each block of submatrixes. In other words, the unweighted supermatrix is raised to limiting powers to calculate the overall priorities, and thus the cumulative influence of each element on every other element with which it interacts is obtained. In this case, it is necessary to raise the unweighted supermatrix to the power , where is an arbitrary large number.

$$W = \begin{array}{r} \\ \text{Goal} \\ \text{Criteria} \\ \text{Sub-Criteria} \\ \text{Alternatives} \end{array} \begin{array}{c} \begin{array}{cccc} \text{Goal} & \text{Criteria} & \text{Sub-Criteri} & \text{Altematives} \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 \\ W_C & W_{\tilde{C}} & 0 & 0 \\ 0 & W_{SC} & W_{S\tilde{C}} & 0 \\ 0 & 0 & W_A & W_{\tilde{A}} \end{bmatrix} \end{array}$$

Figure 3. The unweighted supermatrix

STEP 4: Selection of best alternatives
The overall priorities of alternatives may be obtained through using the limiting process method. Then, alternatives may be prioritized and the best solution can be selected.

3 The proposed method

The QFD helps to identify what is important by providing a logical system to replace emotion-based decision making [16]. As a powerful planning methodology, the QFD associates the effort of a company into a market-in approach to emphasize with customer satisfaction in all phases of product development from initial planning through manufacturing and marketing [25]. Particularly, for coping with complex MCDM matters, the QFD utilizes a series of interactive matrices in which every matrix performs as a translation in order to convert the WHATs into the HOWs, so that it can be employed to address almost any business situation requiring decisions involving a multitude of criteria, requirements or demands [11]. Moreover, benefits of using the QFD matrices are such as: matrices bring together all the essential data to produce a highly visual and compact form; matrices help ones to delivery decisions; matrices promote coordination and communication with others; and facilitate calculations and provide sensitivity analysis on the results [10].

Since the key tool of QFD is the matrix, we focus on the series of interactive matrices and therefore apply the supermatrix of the ANP in order to perform our proposed method. In the proposed method, it incorporates several QFD matrices into a supermatrix based on the Series System model (Figure 2). The procedures of proposed method are mainly divided into two phases as follows.

Phase 1: Using QFD to develop decision structure
In this phase, it begins with the way to confirm strategic needs obtained through business surveys and analyses. Next, it is necessary to define the decision goal and to collect relevant information,

evaluation criteria, and the alternatives. Then, these decision elements are structured into a three-dimension HOQ (Figure 4) through the QFD methodology. Commonly, persons employ the way of traditional two-dimension HOQ, so that they need to use two HOQs with twice translations. Where the first HOQ translates the criteria into sub-criteria, and then the second HOQ converts the sub-criteria into the alternatives. Obviously, the way of using a three-dimension HOQ is more effective and beneficial than that way of using a two-dimension HOQ. Because the former provides more integrated information in a compact form, and it is also more convenient for the calculations with the supermatrix of the ANP. Of course, if necessary, a four-dimension HOQ can also be extended to use.

Phase 2: Using ANP to prioritize alternative
Once that decision structure is settled down, it is required to employ Saaty's nine-point scale for making all paired comparisons of decision elements, and then to incorporate all sub-matrices into the supermatrix (Figure 3) which is a hierarchy structure with four levels including inner dependences. Through performing calculations with the supermatrix of the ANP, finally the overall priorities of alternatives may be obtained. As for the calculations of the supermatrix, we can easily solve it with the ways using either the Microsoft Excel or the professional software named "Super Decisions" provided by the Creative Decisions Foundation.

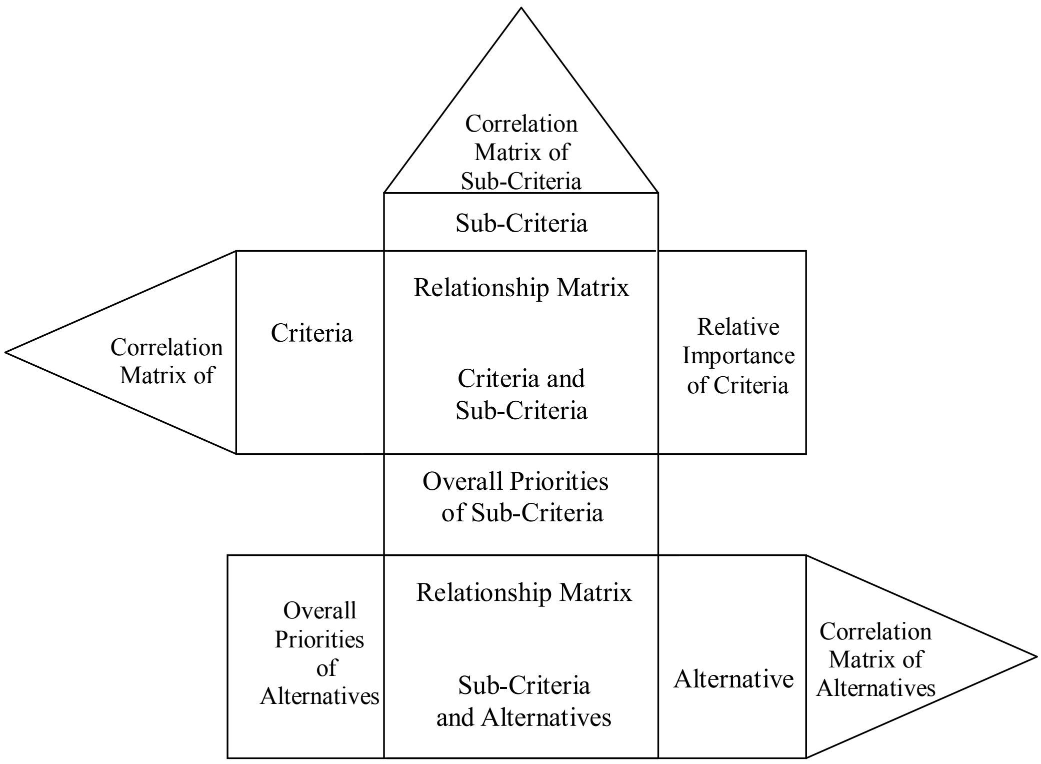

Figure 4. The three-dimension HOQ.

4 An empirical example

To illustrate the usage and advantages of the proposed method with a combined QFD and ANP approach, we here use an empirical example of [29].

4.1 Problem descriptions

For improving attractiveness to soccer enthusiasts, [29] develop a modified QFD model that prioritizes and suggests a set of rule changes in professional sports. They perform successfully with the ways of combining with the AHP and the ANP into the QFD for making better evaluation decisions, and of incorporating these decision factors including Market Segments, Enthusiast Interests, Soccer Activities, and Rules of the Game. The Enthusiast Interests includes: Fun to watch (e1), Fun to play (e2), Safe to play (e3), and Easy to play (e4). The Soccer Activities comprises: Scoring (s1), Saving (s2), Passing (s3), Dribbling (s4), Defending (s5), Shooting (s6), Assisting (s7), and Fouling (s8). The Rules of the Game contains: Fouls & Misconduct (r1), Number of Players (r2), Goals Size (r3), Ball Characteristics (r4), and Offside Law (r5). In addition, both the Soccer Activities and the Rules of the Game have their own inner dependence matrices.

In their modified QFD model, they employ the way of traditional two-dimension HOQ. Therefore, they need to use three HOQs through triple translations. That is, the first HOQ translates the Market Segments into the Enthusiast Interests, the second HOQ converts the Enthusiast Interests into the Soccer Activities, and the final HOQ transforms the Soccer Activities into the Rules of the Game. Additionally, in order to obtain the Overall Priorities of Rules of the Game, their solution is executed with three main stages: (1) using a traditional two-dimension HOQ to get the Overall Priorities of Enthusiast Interests, (2) using a supermatrix to get the Overall Priorities of Soccer Activities, and finally (3) using a supermatrix to get the Overall Priorities of Rules of the Game. However, their solution is not so simple and is required to take much effort. It therefore leaves a room to improve better.

4.2 Applications of proposed method

Instead of their solution, we may handle it more effectively with our proposed method. In the first phase, it is a good way to extend and incorporate those three HOQs into a four-dimension HOQ (Figure 5). In the second phase, in fact, those two supermatrices can be combined into just one supermatrix to calculate the Overall Priorities of Rules of the Game. Hence, all the estimations about Enthusiast Interests, Soccer Activities, and Rules of the Game, that are arranged into an integrated form (Table 1) of the unweighted supermatrix. Then, by raising the unweighted supermatrix to the power until the columns stabilize and become identical in each block of submatrixes, the same result (Table 2) is obtained as [29] did. In rank order by their overall priorities, the three most important Law of the Game are: (1) Number of Players (r2) with a 26.4% weight score, (2) Fouls & Misconduct (r1) with a 25.9% weight score, and (3) Ball Characteristics (r4) with 23.6% weight score.

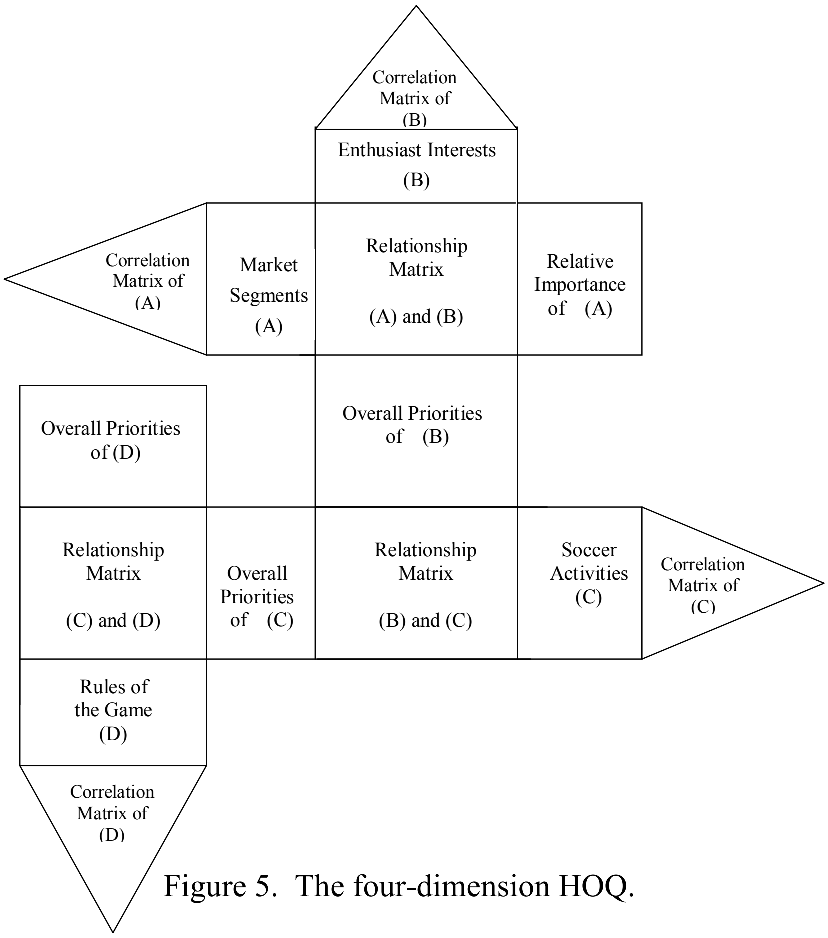

Figure 5. The four-dimension HOQ.

Table 1 The unweighted supermatrix

	Goal	e_1	e_2	e_3	e_4	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	r_1	r_2	r_3	r_4	r_5
Goal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_1	0.324	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_2	0.370	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_3	0.262	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_4	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_1	0.000	0.304	0.293	0.098	0.323	0.500	0.300	0.000	0.000	0.067	0.092	0.313	0.023	0.000	0.000	0.000	0.000	0.000
s_2	0.000	0.234	0.201	0.148	0.067	0.183	0.677	0.000	0.000	0.000	0.055	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_3	0.000	0.029	0.093	0.042	0.133	0.000	0.000	0.677	0.000	0.039	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000
s_4	0.000	0.092	0.088	0.053	0.166	0.000	0.000	0.000	0.500	0.067	0.064	0.041	0.053	0.000	0.000	0.000	0.000	0.000
s_5	0.000	0.000	0.029	0.146	0.053	0.122	0.000	0.167	0.143	0.500	0.229	0.000	0.160	0.000	0.000	0.000	0.000	0.000
s_6	0.000	0.084	0.083	0.047	0.152	0.052	0.033	0.000	0.063	0.104	0.500	0.032	0.000	0.000	0.000	0.000	0.000	0.000
s_7	0.000	0.258	0.213	0.041	0.051	0.122	0.000	0.167	0.070	0.000	0.059	0.500	0.013	0.000	0.000	0.000	0.000	0.000
s_8	0.000	0.000	0.000	0.425	0.055	0.021	0.000	0.000	0.224	0.223	0.000	0.037	0.750	0.000	0.000	0.000	0.000	0.000
r_1	0.000	0.000	0.000	0.000	0.000	0.187	0.000	0.125	0.500	0.507	0.084	0.195	1.000	0.667	0.260	0.000	0.050	0.125
r_2	0.000	0.000	0.000	0.000	0.000	0.223	0.000	0.618	0.500	0.197	0.311	0.391	0.000	0.269	0.667	0.063	0.000	0.125
r_3	0.000	0.000	0.000	0.000	0.000	0.194	0.367	0.000	0.000	0.000	0.261	0.000	0.000	0.000	0.048	0.750	0.150	0.000
r_4	0.000	0.000	0.000	0.000	0.000	0.346	0.498	0.157	0.000	0.178	0.344	0.276	0.000	0.043	0.000	0.188	0.800	0.000
r_5	0.000	0.000	0.000	0.000	0.000	0.049	0.135	0.100	0.000	0.117	0.000	0.138	0.000	0.021	0.026	0.000	0.000	0.750

Table 2 The final supermatrix

	Goal	e_1	e_2	e_3	e_4	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	r_1	r_2	r_3	r_4	r_5
Goal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
e_4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
s_8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
r_1	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259
r_2	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264
r_3	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
r_4	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236
r_5	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049

4.3 Discussions

The QFD is a profitable methodology that serves as a potent tool for logically assuring and improving the alignment of design processes to the customer requirements through a structured and well-documented framework. Now it has been extended to apply for any kind of planning process and decision making, when a cross-functional team desires to logically prioritize their possible solutions. However, there are some issues required to be rectified during the QFD implement process, such as the subjective assessments of using numbers or symbols, the multifarious steps of calculating overall priorities, and the inner dependences of decision elements.

In order to improve those problems, some papers [29][27] have applied the ANP combined with the QFD to handle MCDM problems, but they do not entirely utilize the ANP in their models. For example, they use the AHP to determine the intensity of the relationship between the row and column variables of each matrix, while use the ANP to determine the intensity of synergy effects among column variables. In fact, it is not necessary to employ the AHP in those cases. Because the ANP do the same way as the AHP to derive ratio scale priorities by making paired comparisons of elements, and the AHP is a special case of the ANP. That is, the ANP is more comprehensive than the AHP and free to use for MCDM problems. At least, the supermatrix of ANP is enough to deal with both the relationship between the row and column variables and synergy effects among column variables. Additionally, the work of [18] has well integrated the ANP with the QFD, but it only employ once deployment translation through the supermatrix of a hierarchy structure with three levels including inner dependences.

For enabling ones to tackle the situation with highly complicated issues, our proposed method completely utilizes all natures of the ANP through the ways to make all paired comparisons based on Saaty's nine-point scale, and to incorporate several deployment translations into the supermatrix of a hierarchy structure with four levels including inner dependences. If necessary, the supermatrix of a four-level hierarchy structure and the three-dimension HOQ can also be extended to use. Therefore, our proposed method is more adequate than those above existing methods to cope with complex MCDM matters in the real world.

5 Conclusions

The QFD is a valuable method with the emphasis on goal-oriented and customer-focused approach that provides a means of translating customer needs into the appropriate technical requirements for each stage of detailed operations in product development and production. However, it is required to improve these issues such as subjective assessments, priority calculations, and inner dependences during the QFD implement process. In order to ameliorate the above issues, the use of ANP is a favorable way because the ANP provides an effectual way to cope with complex MCDM matters. The ANP has these advantages such as: handles human intuitive judgment by making paired comparisons with ratio scale, is easy for priority calculations by incorporating several matrices into an integrated supermatrix, and enables us deal with inner dependences without independence assumptions.

Hence, we have developed an effective decision-making method using a combined QFD and ANP approach to help for making better decisions of planning or evaluation problems. Especially, in our proposed method, the supermatrix of a four-level hierarchy structure and the three-dimension HOQ are demonstrated for cope with greatly complicated practical problems. Using our proposed method, all decision information is structured into a concise form which facilitates understanding, communications, calculations, and sensitivity analysis for problem-solving. Especially, the proposed method is comprehensive and applicable to all companies which face to solve multi-criteria issues and desire to seek for better decisions of planning or evaluation problems.

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