Quality Function Deployment: Methods and Modeling Issues

김광재, 포항공과대학교 산업공학과

Abstract

New product development is a complex managerial process which involves multiple functional groups, each with a different perspective. Quality function deployment (QFD) is a new product development process which stresses cross-functional integration. QFD provides a specific approach for ensuring quality through each stage of the product development and production process. This paper provides an overview of QFD including its concepts and methods, and then proposes an integrated approach to formulating and solving the QFD process. This paper also discusses issues associated with the prescriptive modeling of QFD.

1. QFD: Concepts and Methods

Many firms are facing rapid changes due to technological innovations and changing customer demands. Getting high-quality products to customers in a timely manner is crucial for their survival and prosperity in the competitive marketplace. New product development is a complex managerial process which involves multiple functional groups, each with a different perspective. Quality function deployment (QFD) is a new product development process which stresses cross-functional integration. QFD provides a specific approach for ensuring quality through each stage of the product development and production process.

1.1 Definition and Concept

QFD can be defined as an overall concept that provides a means of translating the needs of a customer through the various stages of product planning, engineering, and manufacturing into a final product. In other words, the intent of QFD is to incorporate the "voice of the customer" into all the phases of the product development and production cycle, through planning and into the marketplace.

The basic idea of QFD is to translate the desires of the customer into the design or engineering characteristics of the product, and subsequently into the parts characteristics, the process plans, and the production requirements associated with its manufacture.

1.2 Advantages

The overall objective of QFD is to reduce the length of the product development cycle, while simultaneously improving product quality and delivering the product at a lower cost; a broader objective of QFD is to increase market share. QFD brings various advantages to companies such as fewer and earlier design changes, reduced product development cycle time, fewer startup problems, and easier documentation [1,2]. Other advantages of QFD include fewer field problems, warranty claim reduction, development of cross-functional teamwork, improved design reliability, and, above all, customer satisfaction.

1.3 House of Quality

QFD is accomplished through a series of charts which are a conceptual map, providing the means for interfunctional communications. The chart is usually called a house of quality (HOQ). A typical HOQ of the product planning phase contains information on "what to do" (customer attributes, CAs), "how to do it" (engineering characteristics, ECs), the integration of this information (relationships between CAs and ECs and among the ECs), and benchmarking data.

2. Prescriptive Modeling of QFD

Notwithstanding the rapid growth of QFD literature, development of systematic procedures for setting the target engineering design levels has scarcely been addressed.

2.1 Setting Target EC Levels

Based upon the information contained in a HOQ, "target levels" for the ECs of the company's new or revised product are determined. The process of setting the target levels in practice currently is accomplished in a subjective, ad hoc manner. Given that a HOQ may contain many CAs and ECs, such a process is difficult and lengthy to obtain a feasible competitive design, and virtually impossible to optimize.

After a HOQ chart is completed, it would be extremely difficult and time-consuming to determine the target EC levels without the support of a systematic tool. In order to obtain a good, feasible design, the target setting process should be supported by a tool which can deal with multiple conflicting requirements, complex interrelationships among variables, and inherent vagueness in the design situation.

2.2 Problem Definition

The process of determining target values for the ECs in QFD can be formulated as an optimization problem. Let

y_i = customer perception of the degree of satisfaction of CA_i, i=1,...,m,

x_j = target value of EC_j, j=1,...,n,

f_i = functional relationship between CA_i and ECs, i=1,...,m, i.e., $y_i = f_i(x_1, ..., x_n)$,

g_j = functional relationship between EC_j and other ECs, j=1,...,n, i.e., $x_j = g_j(x_1,..., x_{j-1}, x_{j+1},..., x_n)$.

A multiobjective optimization model can be formulated as follows:

Find EC target values $x_1, x_2, ..., x_n$ which Maximize Overall Customer Satisfaction for attributes $(y_1, ..., y_m)$ (1)

subject to

$y_i = f_i(X)$, i=1,...,m, (2)

$x_j = g_j(X_j)$, j=1,...,n, (3)

where $X = (x_1, ..., x_n)^T$, and $X_j = (x_1, ..., x_{j-1}, x_{j+1}, ..., x_n)^T$. Additional constraints may be added to the above formulation as appropriate.

2.3 Parameter Estimation of Functional Relationships

There are several methodological tools that may be used to describe the relationships between CAs and ECs, and among ECs; for example, multivariate statistical techniques such as regression analysis and conjoint analysis, artificial neural networks, subjective judgments, etc. While the choice of the method depends on the design situation, the use of fuzzy set theoretic techniques such as fuzzy regression [3] is suggested if the size of the data set is small, and the basic relationships given in the HOQ are vague [4], which is often the case in the typical industrial environment.

2.4 Model Formulation

Many design tasks in practice take place in an environment in which the system parameters, objectives, and constraints are not known precisely. One way to deal with such imprecision and vagueness quantitatively is via the concept of fuzzy sets. Fuzziness can be expressed in different ways in the general model given in (1) - (3):

1. system parameters of functional relationships (f_i and g_j) are fuzzy (i.e., possibilistic parameters),
2. customers do not exhibit maximizing behavior, but rather act as satisfiers (i.e., satisficing objectives) because objective functions are fuzzy and not known precisely,
3. constraints are not hard, so that some leeway can be provided on the equality (or inequality) relationships (i.e., flexible constraints).

The combination of a fuzzy objective function and crisp constraints is not practical due to the lack of intuitive appeal in design situations. When the constraints are fuzzy, the use of a crisp objective function (i.e., determination of an extremum of a crisp function over a fuzzy domain) is not appropriate because in very rare real cases a scaling factor between the objective and constraints (and thus solution) can be found which has a real justification [5]. Except for those two cases, a fuzzy model can possess any combination of the aforementioned three types of fuzziness. For details of the model formulation, refer to [6].

2.5 Modeling Issues

There are several modeling issues that need to be considered in the prescriptive modeling of QFD described above. First of all, all the CAs in a HOQ do not have the same weights. The weights will affect the design evaluation criteria and thus the final design. While subjective scales are popular in practice to assess the weights, systematic techniques in multicriteria decision making [7] or analytic hierarchical process [8] can be utilized.

The relationships between CAs and ECs and among ECs are typically assessed using a subjective scale (e.g., (1,3,9) for a weak, medium, and strong relationship, respectively). However, when the attributes are measurable, traditional design of experiments (DOE) and Taguchi method can be advantageously utilized in assessing such relationships. DOE and Taguchi method can help to establish the real relationships between, for example in the product planning stage, CAs and ECs [9,10]. In the parts and/or process planning stages, DOE and Taguchi's parameter design method can be used to resolve tradeoffs, help to determine product and process target values, and quantitatively compare potential design solutions [11].

One of the major difficulties of QFD in practice is the large size of the house. Even for a simple product design, the size of a house can grow very fast. This implies the need for a huge amount time and effort to analyze as well as fill out the HOQ chart. One way to reduce the complexity of a large scale QFD problem is to decompose it into smaller subproblems. Multivariate statistical techniques can be employed to develop such a decomposition methodology [12].

In addition, there are other issues to be resolved in the future such as sensitivity of design parameters to the CA weight changes, checking the validity of system equations, linkage among several houses of quality.

3. Conclusion

QFD is a concept and tool for translating the "voice of the customer" through the various stages of product planning, engineering, and manufacturing into a final product. The basic idea of QFD is to translate the desires of the customer into the design or engineering characteristics of the product. The basic idea of a prescriptive modeling approach to QFD has been presented. Multiattribute value theory combined with fuzzy optimization theory allow the designer to mathematically consider tradeoffs among the various customer attributes as well as the inherent fuzziness in the system. The issues that need to be carefully considered in the modeling of QFD have also been discussed.

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