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An advanced quality function deployment model using fuzzy analytic network process

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A B S T R A C T

Quality function deployment (QFD) is a customer-oriented design tool used to ensure that the voice of customers is employed throughout the product planning and design stages. QFD uses the house of quality (HOQ), which is a matrix that provides a conceptual map for inter-functional planning and communication. In this paper, an advanced QFD model, based on fuzzy analytic network process (ANP) approach, is proposed to systematically take into account the interrelationship between and within the QFD components. The proposed method is aimed at expanding the current research scope from the product planning phase to the part deployment phase to provide product developers with more valuable information (ex. the importance and bottleneck level of part characteristics). Both customer requirements and the company's production demands will be used as the inputs for the QFD process to enhance the completeness and accuracy of the QFD analysis results. A case study is presented to illustrate the application of the proposed method.

1. Introduction

Global competitiveness has recently become the biggest concern of many companies, forced to seek lower cost and higher quality for their products. To achieve that, many companies inevitably face another challenge – how to quickly and efficiently respond to diverse and fast-changing customer demands. New product development that meets various customer demands is critical for the success of a product but also for the survival of a company.

By focusing on listening to customers, quality function deployment (QFD) has been a useful technique that aims to satisfy customer needs at the very beginning, namely the product design phase. As a product design tool, QFD is often used to plan and design new or improved products (or services). QFD is a cross-functional planning tool used to ensure that the customer's voice is translated into product design through a structured framework. In general, a QFD system framework is comprised of four inter-linked phases: product planning, part deployment, process planning, and production planning. The output of one phase is employed in the next phase as an input. Specifically, QFD translates customer requirements (CRs) into engineering characteristics (ECs), and subsequently into part characteristics (PCs), manufacturing operations and production standards. QFD has been successfully applied by industries in both Japan and the US [1,2]. The success of QFD applications may come from some of its benefits, such as high customer satisfaction, potential for breakthrough innovation, low production cost, shorter lead times, better communication through cross-functional teamwork and knowledge preservation [1,3,4].

The QFD process involves various inputs that are assessed by customers or product developers. The assessed values are usually subjective or imprecise. In traditional QFD, they are assumed to be precise and assigned as crisp values. However, it may be more appropriate to treat them as fuzzy rather than precise. To appropriately quantify these subjective, imprecise, or

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uncertain assessed values, a number of researchers have applied the fuzzy set theory to QFD and have developed various fuzzy QFD methods. These methods includes conventional QFD computation using fuzzy variables [5–7], fuzzy outranking [8], entropy [9], fuzzy tendency analysis [10], fuzzy MCDM [11], fuzzy integral [12], fuzzy expected value [13,14], fuzzy goal programming [15], fuzzy expert systems [16], etc.

In addition to the above studies, some researchers adopted a powerful decision-making tool, namely analytic network process (ANP), to address the inner-relationship and interrelationship among the CRs and ECs in QFD. For instance, Partovi [17] employed both AHP and ANP models to quantify strategic service vision as a QFD framework. Karsak et al. [18] developed a systematic decision approach to determine the importance of ECs based on both the ANP model and zero-one goal programming. Partovi and Corredoira [19] followed the Partovi's [17] method to prioritize and design a set of rule changes for the game of soccer. Büyüközkan et al. [20] proposed a fuzzy ANP model to determine the importance of ECs based on the network model used in Saaty and Takizawa [21]. Ertay et al. [22] used linguistic variables as the input for the QFD process and prioritized ECs based on the fuzzy ANP approach similar to Büyüközkan et al.' [20] approach. Kahraman et al. [23] developed an integrated framework to determine the importance of ECs in product design based on both fuzzy QFD and fuzzy optimization models. Partovi [24,25] developed an integrated model based on QFD, ANP and the analytical hierarchy process (AHP) to deal with the facility location problem and the process selection problem, respectively. Raharjo et al. [26] incorporated product development risk, competitive analysis and feedback information with the QFD components in their ANP model to exploit the QFD process. Since the ANP approach can well illustrate the interrelationship between and within QFD components, this study will use it as a basis to develop the proposed method.

From a review of the ANP approaches used in QFD, four issues can be further investigated. Firstly, extant studies concentrate on obtaining the importance of ECs. In other words, they only put the focus on product planning, the first phase of the QFD. The remaining three phases (part deployment, process planning, and production planning) of QFD are seldom addressed in these literatures. Exploration of the subsequent three phases can provide product developers with more valuable information, such as critical component identification, component bottleneck levels, the design parameters, the operation instructions, etc. Such information can help product developers effectively identify critical process and production factors in product development. Hence, the importance of further investigation for the remaining phases should never be underestimated. Secondly, a competitive analysis is usually included in traditional QFD and it can offer product developers with useful information, such as how well a company's product (or its competitor's product) fulfills each customer requirement, how much improvement is needed in a company's product, and how much sales leverage may result from the improvement. Most of the current ANP studies do not take the competitive analysis into consideration. Thirdly, several researchers [15,18,27,28] argued that the establishment of QFD should consider customer needs and also the company's production demands such as production cost, product extendibility, and product manufacturability. The company's production demands may help product developers identify which of the ECs may be more costly, extendible, or easy-manufactured during the product development. The incorporation of company's production demands in QFD can make the QFD analysis results more comprehensive and accurate. However, few studies have paid attention to this issue. Fourthly, in the previous fuzzy ANP approaches [20,22,23], the elements in their supermatrices is defuzzified into crisp values after the pairwise comparison is performed. Thus, the importance of ECs in their approaches was calculated based on crisp values rather than fuzzy numbers. In some perspectives, their approaches are similar to the crisp ANP models used in QFD. Hence, it cannot provide product developers with more advanced information, such as the possible range for the importance of ECs under a certain degree of confidence (or belief).

Aiming to solve these four issues, the objective of this research is to develop an advanced quality function deployment (A-QFD) model based on the fuzzy ANP approach. This study expands the scope of extant studies from the product planning phase to the part deployment phase. In the product planning phase, the A-QFD model takes the competitive analysis into consideration. Furthermore, both customer requirements and company's production demands are used as the inputs of the QFD process. In the part deployment phase, in addition to the importance of part characteristics (PCs), the bottleneck level of PCs is also determined. Fuzzy ranking and fuzzy clustering are employed to prioritize and classify the acquired information. The obtained outputs of the A-QFD model will be fuzzy numbers instead of crisp values in order to provide more detailed information for product developers.

The rest of this paper is organized as follows: Section 2 briefly introduces the concepts of QFD, QFD represented by ANP, and triangular fuzzy number. Section 3 discusses the framework and the detailed steps of the proposed A-QFD approach. Section 4 uses a case company to illustrate the proposed A-QFD method, and the last section concludes the present research.

2. QFD, QFD represented by ANP, and triangular fuzzy number

2.1. Quality function deployment

QFD, which originated in Japan in 1972, was designed to improve quality in product development. It has been a successful tool in assisting product developers systematically incorporate customer requirements into product and process development [2]. According to Hauser and Clausing [1], QFD is a kind of conceptual map which is the mean for inter-functional planning and communication. In general, a QFD system is categorized into four inter-linked phases: product planning, part deployment, process planning, and production planning phases, as shown in Fig. 1.