Available online at www.sciencedirect.com
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European Journal of Operational Research 171 (2006) 390–411
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

O.R. Applications

A fuzzy optimization model for QFD planning process using analytic network approach

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Received 16 September 2003; accepted 2 September 2004
Available online 30 October 2004

Abstract

In both the quality improvement and the design of a product, the engineering characteristics affecting product performance are primarily identified and improved to optimize customer needs (CNs). Especially, the limited resources and increased market competition and product complexity require a customer-driven quality management and product development system achieving higher customer satisfaction. Quality function deployment (QFD) is used as a powerful tool for improving product design and quality, and procuring a customer-driven quality system. In this paper, an integrated framework based on fuzzy-QFD and a fuzzy optimization model is proposed to determine the product technical requirements (PTRs) to be considered in designing a product. The coefficients of the objective function are obtained from a fuzzy analytic network process (ANP) approach. Fuzzy analytic hierarchy process (AHP) is also used in the proposed framework. An application in a Turkish Company producing PVC window and door systems is presented to illustrate the proposed framework.

Keywords: Fuzzy sets; QFD; AHP; ANP; Optimization

1. Introduction

Today, business decisions in many companies involve selecting the products providing a high degree of customer satisfaction to meet multiple objectives. Especially, global competitiveness has recently become the largest concern of many companies, which consider "continuous improvement" to catch up with the

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doi:10.1016/j.ejor.2004.09.016

rapid changing development throughout the world stimulated by technological innovations and changing customers' needs (CNs). In general, a poor product definition commonly leads to either failure of that product in market place or extended product development time. Understanding of CNs leads to successful products and shorter development time. For this reason, product technical requirements (PTRs) or design requirements are generally established by the product design team at an early design stage according to the company's strategic goals. Quality function deployment (QFD) is also a cross-functional planning tool used to help the product development team. The purpose of the technique is to reduce two types of conflict: First, the conflict that the product specification does not comply with the needs of the predetermined target group of customers; second, the conflict that the final product does not comply with the PTRs. To reduce the first conflict, the product specifications, or PTRs must take CNs that are the voice of the customers into account. The second conflict is reduced by additional transformations of PTRs into product parts, ingredients, processes, and production specifications.

There have been some studies on quantifying the planning subjects in HoQ within past decade. Some of these studies focused on being employed fuzzy set theory for prioritizing PTRs or CNs (Chan et al., 1999; Khoo and Ho, 1996; Zhou, 1998; Kim et al., 2000; Shen et al., 2001). Other studies are related to AHP (Saaty, 1980) applied to the HoQ to identify CNs and to generate the relative importances (Armacost et al., 1994; Park and Kim, 1998; Doukas et al., 1995; Fukuda and Matsuura, 1993).

In this study, we propose the use of the analytic network process (ANP) (Saaty, 1996) to incorporate the innerdependence issues into CNs and PTRs in HoQ. ANP enables us to take into consideration the degree of interdependences between CNs and PTRs by means of AHP. Using crisp ANP in QFD has been considered by Partovi (2001), Partovi and Corredoira (2002), and Karsak et al. (2002). We extend these studies by employing linguistic parameters to emphasize impreciseness and vagueness in ANP because of human judgments' subjectivity on the importance of PTRs related to CNs. Besides, in order to determine the set of PTRs, which will be considered in product design, we construct a mixed integer linear programming model to optimize target improvements. The proposed integrated framework can take the difficulties into consideration due to the uncertainty of data and lack of quantitative tools. It prioritizes engineering characteristics through a fuzzy ranking procedure and optimizes the improvements using a mixed integer program.

The paper is organized as the follows. In Section 2, we describe QFD briefly and its literature review. Section 3 presents the ANP and its usage in QFD. In Section 4, we indicate the representation of ANP structure in QFD model. Section 5 summarizes fuzzy QFD and proposed optimization framework. In Section 6, we illustrate an application of the proposed fuzzy framework.

2. QFD and literature review

Quality function deployment (QFD) is namely a key tool for application of concurrent engineering and implementing total quality management (TQM) (Guinta and Praizler, 1993). QFD emphasizes multifunctional teams required for integrating all corporate functions to be responsive to the customer's requirements so that product planning, product design, process planning, and production planning provide a coherent response to CNs. In other words, QFD can be seen as a set of planning tools, which help introducing new or improved products faster to market by focusing on customer satisfaction.

QFD was originally developed and implemented in Japan at the Kobe Shipyards of Mitsubishi Heavy Industries in 1972. It was observed that Toyota was able to reduce start up pre-production costs by 60% from 1977 to 1984 and to decrease the time required for its development by one-third through the use of QFD (Hauser and Clausing, 1988; Ertay, 1998; Hsiao, 2002). Early users of QFD include Toyota, Ford Motor Company, Procter, 3M Corporation, Gamble, AT&T, Hewlett Packard, Digital Equipment Corporation, etc. (Cohen, 1995). Besides, the American Supplier Institute (ASI) in Dearborn, Michigan and