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Fuzzy multiple objective programming framework to prioritize design requirements in quality function deployment☆

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Abstract

Quality Function Deployment (QFD) is a customer-oriented design tool for developing new or improved products to increase customer satisfaction by integrating marketing, design engineering, manufacturing, and other related functions of an organization. QFD aims to maximize customer satisfaction; however, considerations such as cost budget, technical difficulty, etc. limit the number and the extent of the possible design requirements that can be incorporated into a product. This paper presents a fuzzy multiple objective programming approach that incorporates imprecise and subjective information inherent in the QFD planning process to determine the level of fulfillment of design requirements. Linguistic variables are employed to represent the imprecise design information and the importance degree of each design objective. A real-world application illustrates the proposed fuzzy multiple objective decision analysis.

Keywords: Fuzzy sets; Multiple objective decision analysis; Fuzzy multiple objective programming; Quality function deployment; House of quality; Product design

1. Introduction

Strategic quality management is vital in maintaining a competitive edge in today's global marketplace. Quality Function Deployment (QFD) is a customer-oriented design tool that aims to meet customer needs in a better way and enhance organizational capabilities, while maximizing company goals. The basic concept of QFD is to translate the desires of customers into design requirements,

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which are also known as product technical requirements, product features or engineering characteristics, and subsequently into parts characteristics, process plans and production requirements. In order to establish these relationships, QFD usually requires four matrices. These are product planning, part planning, process planning, and production/operation planning matrices, respectively. Product planning matrix translates customer needs into design requirements; part planning matrix translates important design requirements into product/part characteristics; process planning matrix translates important product/part characteristics into manufacturing operations; production/operation planning matrix translates important manufacturing operations into day-to-day operations and controls (Shillito, 1994). Here, we focus on the first of the four matrices, also called the house of quality (HOQ). With its design-oriented nature, the HOQ serves both as a valuable resource for designers and a way to summarize and convert feedback from customers into information for engineers.

A key objective of QFD is to determine directly from the customer what they would expect from a specific product or service. One-on-one customer interviews, focus groups, and in-context customer visits are examples of different approaches to achieve this objective. The most effective results are obtained from the QFD process when the team focuses on the customer needs that are most critical to the success of the product under consideration. Customers take part in this process by indicating their relative importance ratings while considering a product. The listing of design requirements is a way to lead the team in using measurable and actionable statements, which indicate the precise meaning of each customer need in the language of the organization. Brainstorming and making use of a tree analogy are the two principle approaches for defining design requirements. Relationships between customer needs and design requirements are defined by answering a specific question corresponding to each cell in the HOQ.

When the customer needs are objectively measurable through experiments, design of experiments and Taguchi methods may be useful tools for identifying the relationship between customer needs and design requirements (Moskowitz & Kim, 1997; P.J. Ross, 1988). In an article reporting the results of a survey covering more than 400 companies in the US and Japan employing QFD, Cristiano, Liker, and White (2000) stated that the use of analytical tools such as regression and design of experiments in conjunction with QFD was not wide spread possibly due to the high level of imprecision and vagueness involved in product development.

The objective of constructing the HOQ is to maximize customer satisfaction, but considerations such as maximizing the fulfillment of design requirements and extendibility with the minimum level of technical difficulty subject to a budget constraint limit the extent of design features that can be incorporated into a product. This decision problem needs to be addressed using a multiple objective programming approach. In general, importance of customer needs, sales point, degree of relationship between customer needs and design requirements, technical difficulty of changing or maintaining design requirements, and cost of design requirements cannot be assessed by either crisp values or random processes. Linguistic variables and triangular fuzzy numbers appear to be effective means to represent the imprecise design information. The value of a linguistic variable can be quantified and extended to mathematical operations using fuzzy set theory.

In this paper, fuzzy set theory is used to present a multiple objective decision framework that incorporates imprecise and subjective information inherent in the QFD planning process. The rest of the paper is organized as follows. Section 2 contains the literature survey, which is not aimed to be exhaustive and is intended to provide the key milestones of the vast literature on QFD. Section 3 outlines the proposed fuzzy multiple objective decision framework. In Section 4, a real-world application is