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Estimating the functional relationships for quality function deployment under uncertainties

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Abstract

Product planning is one of four important processes in new product development (NPD) using quality function deployment (QFD), which is a widely used customer-driven approach. In our opinion, the first problem to be solved is how to incorporate both qualitative and quantitative information regarding relationships between customer requirements (CRs) and engineering characteristics (ECs) as well as those among ECs into the problem formulation. Owing to the typical vagueness or imprecision of functional relationships in a product, product planning is becoming more difficult, particularly in a fuzzy environment. In this paper, an asymmetric fuzzy linear regression approach is proposed to estimate the functional relationships for product planning based on QFD. Firstly, by integrating the least-squares regression into fuzzy linear regression, a pair of hybrid linear programming models with asymmetric triangular fuzzy coefficients are developed to estimate the functional relationships for product planning under uncertainties. Secondly, using the basic concept of fuzzy regression, asymmetric triangular fuzzy coefficients are extended to asymmetric trapezoidal fuzzy coefficients, and another pair of hybrid linear programming models with asymmetric trapezoidal fuzzy coefficients is proposed. The main advantage of these hybrid-programming models is to integrate both the property of central tendency in least squares and the possibilistic property in fuzzy regression. Next, the illustrated example shows that trapezoidal fuzzy number coefficients have more flexibility to handle a wider variety of systematic uncertainties and ambiguities that cannot be modeled efficiently using triangular number fuzzy coefficients. Both asymmetric triangular and trapezoidal fuzzy number coefficients can be applicable

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to a much wider variety of design problems where uncertain, qualitative, and fuzzy relationships are involved than when symmetric triangular fuzzy numbers are used. Finally, future research direction is also discussed.
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1. Introduction

Being able to perform new product development (NPD) in a short lead time and at a minimum cost is one of core factors for improving competitiveness in the global market. As far as product planning and development decisions are concerned, the use of quality function deployment (QFD) has gained extensive international support. QFD is a widely used customer-driven design and manufacturing tool originated in Japan in the late 1960s [1]. Generally QFD utilizes four sets of matrices called houses of quality (HOQ) to relate the customer requirements (CRs) to product planning, parts deployment, process planning and manufacturing operations [11]. When organizations direct their efforts towards meeting the customer requirements (CRs), internal conflict minimizes, development cycle time shortens, market penetration increases, product quality improves, and customer satisfaction increases, resulting in higher revenues.

HOQ matrices have been frequently used in the industry to help design team undergo product planning [10], i.e., capture the CRs by assessing customer preferences, convert those attributes into engineering characteristics (ECs) and then determine the target levels for ECs of new/improved products to match or exceed performance of all competitors in the target market with limited organizational resources. It is a complex decision process with multiple variables to determine the target levels. In practice, it is normally accomplished in a subjective, ad hoc manner, or a heuristic way, such as using prioritization-based methods to yield feasible design, rather than an optimal one. In order to enhance the QFD methodology, developing more reasonable and effective modeling approach for product planning to determine the target values for ECs of a product, towards the maximum degree of customer satisfaction within limited recourses is usually the focus in the HOQ. And some progress has been made along this line. For product planning modeling approach, see [4,6–9,15,16,19,23–25,28].

In our opinion, the first problem to be solved in the product planning modeling based on HOQ is to incorporate both qualitative and quantitative information of relationships between CRs and ECs as well as those among ECs into the problem formulation. However, the literature has not paid enough attention to this aspect. In most of product planning models and methods mentioned above, the HOQ was usually analyzed in a fairly simplistic manner, namely functional relationships in product planning were determined based on organizational judgment using engineering knowledge. Unfortunately, owing to the typical vagueness or imprecision of these functional relationships, it is difficult to identify them using engineering knowledge. Especially when a given HOQ contains large number of CRs and ECs, many trade-offs have to be made among the degrees of customer satisfaction as well as among the implicit or explicit relationships, and it will become more difficult to determine them using engineering knowledge. The inherent vagueness or impreciseness of functional relationships in product planning arises mainly from these aspects:

(a) The QFD process involves various inputs often in the form of linguistic data, e.g., human perception, judgment on market benchmarking, or evaluation on importance of CRs, which are highly subjective and

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