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An integrated linguistic-based group decision-making approach for quality function deployment

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ABSTRACT

Quality function deployment (QFD) is a well-known customer-driven approach for new or improved product/service design and development to maximize customer satisfaction. A typical QFD analysis process involves a series of group decision-making (GDM) processes, such as determination of the importance of customer requirements (CRs), the relationship between CRs and engineering characteristics (ECs), and the correlation among ECs. Properly handling these GDM processes is essential because it will significantly affect the prioritization of ECs, the target value setting of ECs, and the following deployment phases of QFD. Due to different personal experiences and/or lack of sufficient knowledge and information, decision-makers who participate in the QFD analysis process tend to provide their opinions by using different types and multi-granularity linguistic information, which are inherently vague and imprecise. Unlike most of the previous studies, which excessively rely on fuzzy approaches, this study proposes an integrated linguistic-based GDM approach, which can compute with words directly and avoid the risk of loss of information, to cope with multiple types and multi-granularity linguistic assessments given by a group of decision-makers in QFD activity process. Finally, a numerical example is taken to illustrate the applicability of the proposed approach. The linguistic-based approach can effectively manage the imprecise and vague input information in QFD and facilitate decision-making in product design and development.

1. Introduction

In today's highly competitive global marketplace, customer satisfaction has been a permanent goal for companies to be successful, because increased customer satisfaction will positively impact consumer spending, cash flow, and business performance (Hart, 2007). Quality function deployment (QFD) is one of the widely-used customer-driven approaches for new or improved product/service design and development to fulfill customer requirements (CRs) and maximize customer satisfaction (Akao, 1990; Carnevalli & Miguel, 2008; Chan & Wu, 2005). The core concept of QFD is to collect and then translate the customer requirements (CRs) into engineering characteristics (ECs), and subsequently into part characteristics (PCs), process parameters (PPs) and production requirements (PRs) (Hauser & Clausing, 1988). Accordingly, the typical QFD process consists of four phases, i.e., product planning (also known as house of quality (HOQ), depicted in Fig. 1), parts deployment, process planning, and production planning (Chen & Ko, 2010; Hauser & Clausing, 1988). Among these four phases, the HOQ is of fundamental and strategic importance since it can significantly affect the preciseness of the subsequent deployment phases, and thus attracts the most attention from both theoretical and practical fields (Chan & Wu, 2005; Chen & Ko, 2008; Delice & Güngör, 2009; Wang, 2010; Wasserman, 1993). Many companies have confirmed that a great deal of benefit can be achieved from just completing the HOQ matrix (Han, Chen, Ebrahimpour, & Sodhi, 2001). For this reason, we mainly focus on the HOQ matrix of the QFD system in this work.

The decision making process in QFD is a knowledge-intensive activity, while data available in the early stage of new product design is often limited and inaccurate (Chen, Tang, Fung, & Ren, 2004; Kim, Moskowitz, Dhingra, & Evans, 2000). Therefore, it is too complex or too ill-defined for the decision-makers to be amenable for description in exact numerical values (Lin, 2008). It is more suitable to provide their preferences by means of linguistic variables rather than numerical ones (Herrera & Martínez, 2000; Liu, 2009; Xu, 2008, 2009; Zadeh, 1975). In fact, linguistic terms have been proved intuitively easy to be used in expressing the decision makers' assessments with vagueness and imprecision (Kulak & Kahraman, 2005). By transforming the linguistic terms into fuzzy numbers, fuzzy set theory was introduced in QFD and various fuzzy QFD models were proposed to deal with the inevitable

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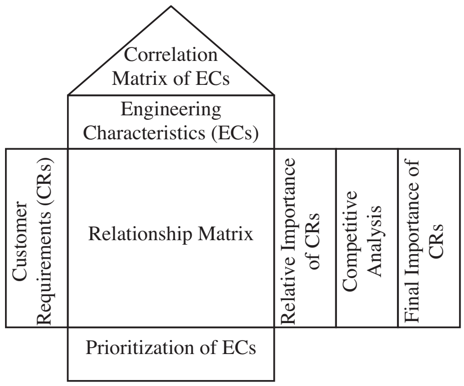

Fig. 1. The house of quality.

vagueness and uncertainty in the decision-making process (Chan & Wu, 2005; Chen & Ko, 2008; Chen et al., 2004; Khoo & Ho, 1996; Kim et al., 2000; Liu, 2005). For more details about fuzzy QFD, please refer to the review given by Chan and Wu (2002) and Carnevalli and Miguel (2008).

On the other hand, although the QFD analysis process is a typical group decision-making (GDM) problem, collaborative decision-making is not an emphasized issue in QFD studies (Feyzioglu & Büyüközkan, 2008). Among the enormous QFD literatures, Ho, Lai, and Chang (1999) proposed an integrated GDM method to determine the relative importance weights of CRs. However, the inherent vagueness and uncertainty in the decision-making process of QFD is not discussed in Ho et al., 1999Ho et al.'s (1999) method. To capture the uncertainty and fuzziness in the decision-making process, Liu and Wu (2008) presented a fuzzy group decision-making approach to determine the importance of CRs and the relationship between CRs and ECs. Moreover, people participating the construction of HOQ tend to give their own preferences information in many different ways, depending on their different background. Thus, Büyüközkan, Feyzioglu, and Ruan (2007) proposed a fuzzy GDM approach to fuse multiple preference formats (i.e., ordered vector, utility vector, subset selection method, linguistic preference relations and fuzzy pair-wise comparisons) to respond CRs. However, all the decision-makers involved in the construction of HOQ are treated equally in the above method. Therefore, Feyzioglu and Büyüközkan (2008) studied a GDM approach that took into account multiple preference formats and the importance of each decision-maker, and then fused different expressions into a uniform group decision by using fuzzy set theory.

In real-world product development problems, the decision-makers may have different cultural and educational backgrounds and different understanding levels of the developing product, and thus, the decision-makers usually provide their preferences information using linguistic terms from linguistic label sets with different granularities (Herrera, Herrera-Viedma, & Martínez, 2000; Xu, 2009; Zhang & Chu, 2009). For example, when comparing the relative importance between each pair of CRs, some experts are willing to use a linguistic label set with five terms (e.g., 1-very unimportant, 2-unimportant, 3-fair, 4-important, 5-very important) while others prefer to use another one with seven terms (e.g., 1-absolutely unimportant, 2-strongly unimportant, 3-weakly unimportant, 4-fair, 5-weakly important, 6-strongly important and 7-absolutely important). To solve this problem, Zhang and Chu (2009) proposed a fuzzy GDM approach incorporating with two optimization models to aggregate multi-format and multi-granularity linguistic judgments in QFD.

Prior studies (Büyüközkan et al., 2007; Feyzioglu & Büyüközkan, 2008; Ho et al., 1999; Liu & Wu, 2008; Zhang & Chu, 2009) have significantly advanced GDM analysis in QFD. Notably, in these studies, fuzzy approaches have been widely used to manage the vague and uncertain information in QFD. The use of fuzzy logic approach in QFD may improve the correctness or precision of the analysis results. However, fuzzy approaches have some inherent drawbacks. First, the calculation results of the fuzzy QFD models rely much on the defuzzification methods they choose (Shen, Tan, & Xie, 2001; Wang, 2010), which increases the decision-makers' subjectivity obviously and poses a potential risk for loss of information. Second, selection of an appropriate membership function in fuzzy set is difficult and affected by the subjective experience (Li, Tang, Luo, & Xu, 2009; Pawlak, 1997; Zhai, Khoo, & Zhong, 2009). Last but not the least, fuzzy arithmetic operations may lead to the enlargement of the resultant fuzzy intervals (Zhai et al., 2009).

In fact, it is not necessary to transform linguistic terms into fuzzy numbers, the linguistic-based decision-making theory developed in recent years can accomplish the processes of computing with words (CW) without loss of information (Herrera & Martínez, 2000; Herrera et al., 2000, Herrera, Herrera-Viedma, & Martínez, 2008; Xu, 2004, 2008, 2009). Recently, Wang (2010) proposed a complete linguistic-based QFD model, which could enhance the tolerance capability of the calculation results. However, in Wang's (2010) study, all the decision-makers involved in the construction of HOQ are treated equally, assuming they used totally identical linguistic granularities and formats to present their judgments and ignoring the importance weights of decision-makers. In other word, GMD problem in QFD is not considered in Wang's (2010) study. Furthermore, due to the estimation inaccuracies, lack of knowledge, and decision-makers' limited expertise related with problem domain, the linguistic preference information given by experts can be in the form of uncertain linguistic information (Xu, 2004). For example, when evaluating the importance degree of customer requirement "quiet washing" of a washing machine, a customer may use uncertain linguistic terms, e.g., at least 'slightly important', to express his/her opinion. However, the uncertain linguistic information is also not addressed in Wang's (2010) work.

In the GDM process of practical QFD application, the decision maker may provide different types of linguistic information, i.e., traditional linguistic variables and uncertain linguistic variables with multi-granularity, depending on their cultural, educational backgrounds and value systems. To the best of our knowledge, there is no linguistic-based GDM approach for QFD, in which multiple types and multi-granularity linguistic information given by a group of decision-makers are considered. Herein, in this study, we propose a direct and complete linguistic-based GDM approach to aggregate these assessments and better reduce the bias for GDM in QFD.

The rest of the paper is organized as follows. The basic concepts of linguistic variables and linguistic label sets are briefly introduced in Section 2. A new integrated linguistic-based GDM approach for QFD is presented in Section 3. The following section gives a numerical example to demonstrate the proposed methodology, and finally, Section 5 concludes the present research.

2. Linguistic label sets and linguistic variables

In practical QFD applications, customers or product developers usually provides his/her perception, judgment and evaluation with linguistic terms (Chan & Wu, 2005; Liu, 2009; Wang, 2010). The linguistic scales or label sets of the linguistic variables they used are uniformly and symmetrically distributed, which are intuitively simplex and lack of reasonable theoretic foundation. However, in group negotiation process, which is a typical process in the building of HOQ, the unbalanced linguistic information appears