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Construction of house of quality for new product planning: A 2-tuple fuzzy linguistic approach

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ABSTRACT

A house of quality (HOQ) diagram is used to analyze the critical factors involved in the quality function deployment (QFD) processes for the new product planning (NPP). The principal tasks of the QFD acting process comprise describing and scoring customer requirements (CRs); determining design requirements (DRs), the relationship between CRs and DRs, the correlations among CRs, and the correlations among DRs. Finally, the DRs can be scored by these assessments in NPP. This study proposes various methods of scoring the requirements of current and potential customers to reflect the knowledge and preference differences among different customers regarding CRs. The CR scores provided by different customers can be assessed by using linguistic, numerical, and interval values, or can be assessed using linguistic label sets with different granularity. A 2-tuple fuzzy linguistic computational approach is adopted to aggregate the CR importance scores obtained from customers by using various methods. In addition, to accurately rate the DRs, a modified relationship between CRs and DRs is proposed. The proposed HOQ construction model is practical because it prevents the loss of information during the QFD process for NPP. An example is used to demonstrate the applicability of the proposed model.

1. Introduction

Quality function deployment (QFD) is a customer-oriented analytical tool that is widely used in new product development (NPD) and product improvement. QFD provides a systematic approach for translating customer requirements (CRs) into design requirements (DRs) to meet customers' expectations by bridging the perception gap between customers and a QFD team, distinguishing the company from its competitors in dynamic and global markets. Since QFD was introduced in the mid-1960s, researchers and companies in several industries and professional fields have successfully used QFD to improve the quality of new product planning (NPP), design, and development, as well as the communication relating to groups, teamwork, and customer satisfaction [1–6]. In the NPP process, a house of quality (HOQ) diagram (Fig. 1) is used to describe the value of the factors involved in QFD processes, including customer requirements (CRs), design requirements (DRs), relationships between CRs and DRs, and correlations among the DRs [7,8]. Fig. 1 shows the structure of a HOQ. A QFD team consists of experts and designers who identify and manage a set of requirements expressed by various customers score CRs according to their value in the NPP based on various customer assessments, and develop numerous DRs that affect the CRs. Furthermore, a QFD team evaluates the relationships between CRs and DRs and the correlations among the DRs, as well as scores the DRs.

Scoring the CRs is a critical task, especially when the process is implemented with numerous customers during the early stage of the QFD processes. The scores of the CRs are determined using various approaches. Carnevalli and Miguel [4] indicated that, in most of the literature, the CRs are scored by using brainstorming and effect–cause–effect diagrams in focus groups sessions, the Kano model, and fuzzy logic. For example, researchers have employed the Kano model [9,10], fuzzy numbers [11,12], and fuzzy logic inference [13] to classify, determine, and derive the scores of the CRs. Because some researchers have viewed scoring the CRs as a form of multi-criteria decision making, they employed the analytic hierarchy process (AHP) [14], the fuzzy AHP [15], and the fuzzy analytic network process (FANP) [16,17] to score the CRs during QFD processes. However, these studies ignored the practical scenario of group decision-making (GDM) in evaluating the CRs. The numerous studies have adopted the GDM approach to score the CRs in QFD processes. Kwong et al. [11] used linguistic terms employing fuzzy numbers to classify customer needs. Karsak [18]

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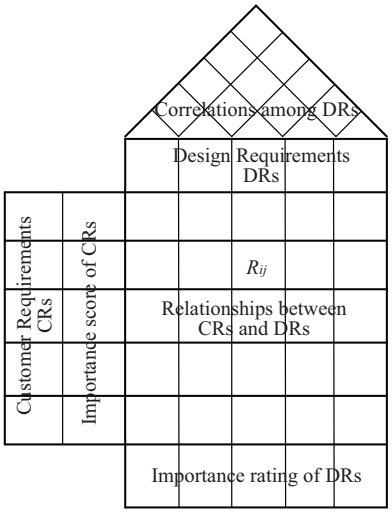

Fig. 1. The house of quality (HOQ).

and Chen and Ko [19,20] employed Kaufmann and Gupta's idea [21] and adopted the fuzzy Delphi method gathering the opinions of current and potential customers to score the CRs based on Bojadziev and Bojadziev's [22] consensus measure. Ho et al. [23] proposed an integrated group decision-making system to score the CRs. However, these studies only adopted a unique format to represent the assessments of the CRs. In practice, the unique representation format might not satisfy the GDM process. Chen et al. [24] proposed using a systematic procedure to score the CRs by using a GDM approach and developed a modified fuzzy clustering approach to identify a consensus among the various perspectives of different experts in a fuzzy environment. Ertay et al. [25] employed a fuzzy weighted average as a fuzzy group decision-making approach to combine multiple preference score to determine the weights of the CRs. Büyüközkan and Feyzioğlu [26] and Büyüközkan et al. [27] proposed a uniform group decision-making approach to aggregate the various evaluation methods that different decision makers used to score the CRs by applying fuzzy sets to collaborative circumstances. However, only current customers were considered in these studies, and the potential customers' opinions in the CR evaluation process were ignored. Unlike the existing approaches, multiple forms of information (i.e., non-homogeneous information) are considered in this study to score the requirements of current and potential customers and reflect the knowledge and preference differences among them in the CR evaluation process. The scoring of the requirements of different customers can be represented as either linguistic, numerical, or interval values or can be assessed using linguistic label sets that have different granularities. This study adopts a 2-tuple fuzzy linguistic computational approach [28], which is an extension of the symbolic model [29], to aggregate the scores of the CRs from different customers by using various methods because it performs adequately in a non-homogeneous information management context [30–32]. Current and potential customers were considered experts and the Delphi method was employed by using the non-homogeneous information to score the CRs.

Conversely, the evaluation of other information in HOQ, such as the relationships between CRs and DRs, and the corrections of the DRs is determined by the QFD team members, who work in the same firm. QFD members usually apply a scale system by using the same language and rules for the evaluation activities, such as 1-3-9, or 1-5-9, which represent linguistic expressions such as "weak," "moderate," and "strong" [7,8], or represent fuzzy sets [19,20,33–37], because these assessments are usually fuzzy during the NPP process. Some researchers have also adopted the GDM perspective to determine the relationships between CRs and DRs, and the modifications of DRs in the HOQ diagram. Although the GDM scenario and the multiple types of presentation of the various members of the QFD teams were considered in Büyüközkan and Feyzioğlu [26] and Büyüközkan et al.'s studies [27], the correlations among DRs were ignored in these studies. In general, a QFD team, especially emphasized cross-functional work for NPP, adopts unique rules with same language in the evaluation processes to communicate efficiently during QFD activities. To replicate this practical feature, the 2-tuple fuzzy linguistic representation model was adopted as a unique representation method in this study. QFD teams can adopt to represent their assessments for HOQ construction.

Unlike the conventional HOQ model, the correlations among the CRs are considered in the proposed HOQ construction model. In the conventional HOQ, the relationships R_{ij} represents the degree to DR_j, affects CR_i. Considering that assessments of the correlations among the CRs to CR_i and the correlations among the DRs to DR_j might affect the initial assessment of R_{ij}, a modified relationship is proposed by combining the initial assessment of relationships R_{ij}, the correlations among the CRs to CR_i, and the correlations among the DRs to DR_j to reflect the influence from the correlations among the CRs and the correlations among the DRs to obtain the more reasonable assessments of relationships in HOQ model. Based on the CR scores and the modified relationships between CRs and DRs, the scores of the DRs can be determined by using the 2-tuple fuzzy linguistic computational approaches.

The remainder of this paper is organized as follows. Section 2 introduces the various methods of assessing the CRs, the 2-tuple fuzzy linguistic representation model, and the aggregation model of the non-homogeneous information from which the 2-tuple fuzzy linguistic computational approaches are adopted to score the CRs. In the aggregation model, the 2-tuple fuzzy Delphi method is proposed to assess the consensus regarding each CR. Section 3 presents the use of the 2-tuple fuzzy linguistic representation model in QFD construction procedures. The modified relationships between CRs and DRs are also described. Section 4 provides an example of a semiconductor packing case to demonstrate the applicability of the proposed QFD construction model. A fuzzy HOQ construction model is discussed and compared with the proposed model. Finally, Section 5 presents this study's conclusion.

2. Assessment forms and aggregation model for CRs evaluation

In this study, the scores of the CRs were determined by using various assessment forms from current and potential customers to reflect the differences in their knowledge, expression, and preferences. The importance scores of the CRs from different customers could be represented using linguistic, numerical, and interval values [32,38,39] because of their common use, or can be assessed in the linguistic label sets with different granularity [32,40], which were necessary to evaluate different degrees of uncertainty regarding the CRs. To aggregate the various assessments of the CRs, an aggregation model was proposed to homogenize the uniform format by converting the assessments from various representation forms into a defined linguistic domain, namely a basic linguistic term set (BLTS) [40]. The consideration of how to select the BLTS is also included in [40]. The BLTS is illustrated in Fig. 2. In Fig. 2, the linguistic terms in the BLTS could be defined as a fuzzy number in accordance with the fuzzy set theory. In order to aggregate the various assessments of the CRs, the various assessments from different customers could be transformed from fuzzy sets in a BLTS into a 2-tuple fuzzy linguistic representation model. Besides, to obtain consensual outcomes from the CRs evaluation, the Delphi method was applied in this aggregation model. The various representation formats of the assessment, 2-tuple fuzzy linguistic representation model,