Available online at www.sciencedirect.com
ScienceDirect
Expert Systems with Applications 36 (2009) 2651–2658
Expert Systems with Applications
www.elsevier.com/locate/eswa

Robustness indices and robust prioritization in QFD

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Abstract

The prioritization of engineering characteristics (ECs) provides an important basis for decision-making in QFD. However, the prioritization results in the conventional QFD may be misleading since it does not consider the uncertainty of input information. This paper develops two robustness indices and proposes the notion of robust prioritization that ensures the EC prioritization to be robust against the uncertainty. The robustness indices consider robustness from two perspectives, namely, the absolute ranking of ECs and the priority relationship among ECs. Based on the two indices, robust prioritization seeks to identify a set of ECs or a priority relationship among ECs in such a way that the result of robust prioritization is stable despite the uncertainty. Finally, the proposed robustness indices and robust prioritization are demonstrated in a case study conducted on the ADSL-based high-speed internet service.

Keywords: QFD; EC prioritization; Robustness; Uncertainty; Variability

1. Introduction

QFD is a mechanism for translating the 'voice of customer' into the 'language of engineers' through various stages of a new product development. Ideally, the translation uses a chart, called "house of quality (HOQ)". A set of typical components of an HOQ include the customer attributes (CAs) and their relative weights, the engineering characteristics (ECs), the relationship matrix between CAs and ECs, the correlation matrix among ECs, the CA and EC benchmarking data, and the EC importance (ECI) values and their target levels.

The basic intent of the QFD is to prioritize the ECs by utilizing the information given in the HOQ. Once the ECI values are computed, the ECs are prioritized simply by comparing the ECI values. The EC prioritization is used as the basis for making important decisions in a new product development such as the selection of some important ECs or the building of priority relationships among ECs (Chan & Wu, 2002).

In the conventional QFD, such analyses are conducted under an assumption that all the input information is certain. However, since the focus of QFD is placed on the early stage of a new product development, uncertainty in the input information of QFD is inevitable (Kim, Moskowitz, Dhingra, & Evans, 2000; Xie, Tan, & Goh, 2003). The effect of uncertainty is propagated into ECI values. Hence, the EC prioritization can be misleading if uncertainty is neglected. The subsequent decisions based on improper prioritization will cause serious problems in a new product development.

To avoid misleading EC prioritizations, uncertainty itself or the effect of uncertainty on prioritization decision should be reduced. The reduction of uncertainty itself is very difficult, if not impossible, and costs dearly. On the other hand, the reduction of the effect of uncertainty is a realizable solution. The reduction of the effect means that prioritization decisions should be made in a robust manner in order that the prioritization decision may be relatively stable despite the given uncertainty. This idea is analogous to that of a robust design in the Taguchi method (Taguchi, 1993).

The quantification of the effect of uncertainty is the first step to be considered in reducing the effect. The effect of

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doi:10.1016/j.eswa.2008.01.067

uncertainty can be measured by the stability of prioritization decision, called robustness. This paper proposes two robustness indices to measure the robustness from two different perspectives – the absolute ranking of ECs and the priority relationship among ECs. A high (low) value of robustness index indicates that the effect of uncertainty on the prioritization decision is low (high), respectively.

In an effort to reduce the effect of uncertainty based on the robustness indices, this paper also proposes a methodology that prioritizes ECs to maximize the value of robustness indices, called 'robust prioritization'. Robust prioritization is a kind of goal programming where the robustness indices are substituted for the objective functions to be maximized.

Section 2 describes the limitation of EC prioritization in the conventional QFD. Section 3 proposes two robustness indices and robust prioritization. The robustness indices and robust prioritization are demonstrated through a case study in Section 4. Section 5 discusses additional issues related to robustness evaluation and robust prioritization of ECs. Finally, concluding remarks are given in Sections 6.

2. Limitation of EC prioritization in the conventional QFD

In typical QFD applications, a cell (i,j) in the relationship matrix (ith row, jth column) of an HOQ chart is assigned 1, 3, 9 (or 1, 3, 5) to represent a weak, medium, and strong relationship, respectively, between CA_i (ith CA) and EC_j (jth EC). The ECI value is computed using the CA weights and the corresponding relationship coefficients. For each EC, the ECI value is computed as

$$\text{ECI}_j = \sum_{i=1}^{m} w_i f_{ij}, \tag{1}$$

where ECI_j is the ECI value of EC_j $(j = 1,\ldots,n)$, w_i is the relative weight of CA_i $(i = 1,\ldots,m)$, and f_{ij} is the relationship coefficient between CA_i and EC_j.

In general, multiple customers are involved in the evaluation of input information of QFD, such as w_i and f_{ij}. Since each customer may have a different opinion, the input information must have uncertainty associated with the heterogeneity of multiple customers (Koksal & Findikoglu, 1998). This uncertainty is inevitable in practice. The conventional QFD does not consider uncertainty, and uses a representative value such as a mean, instead.

For example, in a QFD study on high-speed internet service conducted by the authors, thirty customers were involved in evaluating eleven CA weight values. The CA weight values evaluated by each customer are denoted $w_i(k)$, which means ith CA weight value evaluated by kth customer $(i = 1,\ldots,11;\ k = 1,\ldots,30)$. The HOQ in the QFD study is given in Fig. 1. The CA weight values given in Fig. 1 indicate the mean values $(\overline{w}_i = \frac{1}{30}\sum_{k=1}^{30} w_i(k))$ of the thirty customers. The conventional QFD study neglects the inherent uncertainty and computes the ECI values using Eq. (1), with $\overline{w}_i$ substituted for w_i. As a result, $\overline{\text{ECI}}_j$ can be computed, which denotes jth ECI value computed using $\overline{w}_i$. Based on the $\overline{\text{ECI}}_j$, the EC prioritization is conducted in the conventional QFD. (The details of the case study are described in Section 4.)

However, the EC prioritization in the conventional QFD can be misleading because of variability of ECI

ECs / CAs			$\overline{w}_i$	Network Quality					Customer Service Quality								
				EC1: Download speed	EC2: Upload speed	EC3: Packet transfer delay	EC4: Packet loss rate	EC5: Connection success rate	EC6: In-time installation rate	EC7: Early defect rate	EC8: Defect report rate	EC9: Defect rate	EC10: Defect repair rate	EC11: Time to announce trouble	EC12: Response rate	EC13: Error rate in billing	EC14: Error correction rate in billing
Network	Speed	CA1: Guarantee of speed	0.2680	○	△	◉	△										
		CA2: Minimization of speed variability	0.2012	○	△	○	△										
	Availability	CA3: Availability	0.0790		◉							◉	○				
		CA4: Ease of connection	0.1960	○			○	◉				◉					
Customer Service	Subscription	CA5: Ease of subscription	0.0235						◉								
		CA6: Accuracy	0.0278						◉	◉	○					○	
	Customer support	CA7: Access	0.0204												○	△	○
		CA8: Responsiveness	0.0280						○		◉	◉	◉	○	◉		○
		CA9: Reliability	0.0320						○	○	○		△			◉	○
	Billing/Charge	CA10: Adequacy of charge	0.0840			△											
		CA11: Flexibility of charge option	0.0450			△											
$\overline{ECI}_j$				1.995	1.180	3.144	1.057	1.764	0.641	0.346	0.431	2.727	0.521	0.084	0.313	0.391	0.241

MATRIX		WEIGHTS
Strong	◉	9
Medium	○	3
Weak	△	1

Fig. 1. The HOQ for the high-speed internet service.