Corrective TIR Determination with Reflecting Effectiveness and Adjusting Relationship Strength

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Abstract

The customer unsatisfaction in the new products exists, though the most of enterprises using QFD. It is mainly caused by the failure of corrective determination of technical importance rating(TIR). To derive the technical importance rating, the impact of the fulfillment of design requirements on the satisfaction of customer requirements must first be quantified. This has been accomplished through the use of a 1-3-9 or a 1-5-9 scale and ignored the peak of the house of quality(HOQ). In this paper we suggested the methodology reflecting effectiveness among engineering characteristics and adjusting the relationship strength between customer attribute(CA) and engineering characteristic (EC), by using limit probability and PCMR(pairwise comparison and median rank). With using this method, the determination of TIR would be more suitable for the voice of customers objectively. Here negative correlation is ignored.

1. Introduction

Quality function deployment(QFD) is a management tool that provides a visual connective process to help teams focus on the needs of the customers throughout the total development cycle of a product or process. It provides the means for translating customer needs into appropriate technical requirements for each stage of a product/process-development life-cycle.[8] The thing that makes QFD unique is that the primary focus is the customer requirements. The process is driven by what the customer wants, not by innovations in technology.[4] Consequently, more effort is involved getting the information necessary for determining what the customer truly wants and substituting the customer needs for technical engineering characteristics accurately. But a third goods which the enterprises using QFD producted are fail to be encashed, because of the unsatisfaction of customers' needs. The customer unsatisfaction is mainly caused by the failure of corrective TIR determination. To derive corrective TIR, the impact of the fulfillment of design requirements on the satisfaction of customer requirements must first be quantified. This has been accomplished through the use of a 1-3-9 or a 1-5-9 scale to denote weak, medium, and strong relationships between customer and design requirement pairs. Moreover the peak of HOQ was ignored which show the effectiveness among EC's.

Although there have been studies on the method of relationships between EC's, there are few on the methodology which reflects the effectiveness on determining the TIR. The conventional papers have vaguely dealed with relationship strength between CA and EC, matching them by 1-3-5 or 1-3-9. This methodology is simple, but has a few problems. First, the process of determining relationship strength is vague and arbitrary. Second, despite of the most important part in the HOQ, the roof which describe effectiveness among EC's is not used for determining the TIR. Such an ignorance results in omitting the important EC which shold be considered.

In this paper we present an approach to more correctly reflect what the customer wants. Strength of relationship between CA and EC has been ill-defined[8]. To make up for the weak points, fuzzy logic which can model vagueness in data and/or relationship in a formal way has been used. Khoo and Ho used symbols which represent the customer demands and engineering characteristics(strong, medium, weak) to fill the relationship matrix and build the house of quality, in the fuzzy logic-based approach.[6] Instead of using exact values, the range of values can be used to represent the vagueness in those three relationships in Masud and Dean's study.[1] But we solve the problem with PCMR. This methodology could take an objective view but the procedure is simple. It is very useful to prevent minority to inflate or deflate relationship strength.

HOQ is complex to solve the effectiveness among EC's. For example, we assume that there are three ECs, A, B, and C. A is influenced by B with 0.3(30%), but B is influenced by C with 0.2(20%). How much is A influenced by C? If there are many EC's and multiple influence phases, it is more complex. This is why the effectiveness has been reflected in vague to determine TIR. Here limit probability which means a steady-state considering initial condition is used..

The proposed methodology would be effective

Table 1. The need for adjusting relationship ranking by PCMR

		Priority	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	demand weight	relative demanded weight
customer requirement	QA1	0.1	◎	◎	◎	◎	◎	◎	◎			6.3	0.28
	QA2	0.9								◎	◎	16.2	0.72

(EC1–EC9: engineering characteristic)

◎ : 9 points ○ : 3 points △ : 1 points

		Priority	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	demand weight	relative demanded weight
customer requirement	QA1	0.1	0.9259(1)	0.8194(2)	0.7129(3)	0.6065(4)	0.5000(5)	0.3935(6)	0.2871(7)	0.1806(8)	0.0741(9)	0.45	0.1
	QA2	0.9	0.0741(9)	0.1806(8)	0.2871(7)	0.3935(6)	0.5000(5)	0.6065(4)	0.7129(3)	0.8194(2)	0.9259(1)	4.05	0.9

(EC1–EC9: engineering characteristic)

and useful to reflect customer needs on TIR with objective and ease.

2. Outline of the proposed methodology and backgrounds

2.1 PCMR(pairwise comparison and median rank)

The likert type, i.e. 1-3-5 or 1-3-9, is very subjective. If there are many EC's which are related with a CA, which EC has strong , medium, or weak relationship? It depends on one's individual viewpoint. Therefore the value of relationship strength is various by person. Consider the exaggerated example described by Table 1. In this example, there are two customer requirement-QA1, a relatively unimportant customer requirement with a degree of importance rating of 0.1; and QA2, a relatively important customer requirement with a degree of importance rating of 0.9. There are nine EC's. Note technical characteristic EC1 - EC7, respectively, each strongly related to the relatively unimportant customer requirement,. QA1. On the other hand, EC8 and EC9 are related to the important customer requirement, QA2. The relative demanded weights for the customer requirements, QA1 and QA2, are shown as 0.28 and 0.72. In this example, it is evident that the contribution of engineering design requirement to overall customer satisfaction, as measured by the relative demanded weights for each customer requirement is out of proportion with respect to the relative priorities established for each customer requirement, 0.1 and 0.9, respectively. To remedy this problem Lyman uses normalization transform on the relationship values in relationship matrix[3], but we use PCMR.

The PCMR could prevent the distortion by scaling each EC relationship strength. Moreover it is more simple and objective. That which is more important, A or B is easier and objective than that how much important. And its most significant feature is that an amateur can easily rank relationship strength by comparisons. The rank is determined by the total score of superior.[10]

The ranking should be converted by median [0,1] to compare the different group which has different number of elements. We call it median rank. Median rank is originally used to obtain an estimate of the unreliability for each failure in statistical sense[5]. This estimate is based on a solution of binomial distribution. Here the median is the point in the data set where half of the data elements fall on either side and is important centering constant especially in cases where the mean of the distribution does not exist.[9] The median rank is converted value of ordinal number of which a group is ordered by rank. The property of median rank of a group is mean value 0.5 regardless of the group size. Therefore it could be an unbiased estimator. The value of median rank is altered with the size of sample. For example, 1 of 10's median rank is .0670. But 1 of 7's median rank is .0943. We use PCMR in determining QA priority and relationship strength.

2.2 Limit probability and its application

Limit probability is the process that will be in state j at time n, also equals the long-run proportion of time that the process will be in state j in the Markov process. The peak of the house could be considered into $n \times n$ matrix of an Markov process, and the matrix satisfies ergodic condition which is irreducible, aperiodic, and positive recurrent.[7] In this paper limit probability means that an EC would be effectiveness against other EC's including itself, that is, $P_{i,j}$ is a proportion by which EC i effects EC j. Using the limit probability, we could adjust the TIR to determine correctly.

2.3 Outline of procedure

The outlines of the proposed model in this paper as follows.

Step 1 Classify the customer requirement. KT method is used, because of the customer's ignorance of engineering characteristics.

Step 2 Prioritize the CA's, using PCMR in each group level.[10]

Step 3 Substitute the CA's for EC's.

Step 4 Determine the relationship strengths between each CA and EC's with PCMR.

Step 5 Evaluate the EC's effectiveness against themselves. The value of effectiveness is [0,1] such that the sum of a row is equal to 1. If there exists negative effectiveness, then its value is 0.

Step 6 Calculate the value of steady-state which means that EC's effect themselves infinitely. Using limit probability, we could easily obtain the level that EC i effects EC j through multiple phases.

Step 8 Obtain the adjusted TIR, multiplying effectiveness value on step 7 by value on step 6.

Step 7 Determine the TIR by obtaining the total of each EC's column weight which is calculated by multiplying CA's priority and relationship strength.

The rest of procedure follows the conventional QFD process.

3. Numerical Example

There are the 3rd level QA 19, the 2nd level QA 7, and the 1st level QA 3. The QA priorities are determined by step 2. The result is shown in Table 2. Especially the 1st and 2nd level priorities are reflected to maintain the objective.[]

Table 2 QA Priorities with PCMR(weight coefficient 1,1,2 at level 1,2,3)

	$Q_{.}$	$Q_{..}$	$Q_{...}$	priority $Q_{M.}+Q_{M..}+2Q_{M...}$
QA level (rank) median value	$Q_1(3)$ 0.21	$Q_{11}(3)$ 0.21	$Q_{111}(4)$ 0.16	0.58
			$Q_{112}(3)$ 0.39	0.81
			$Q_{113}(2)$ 0.61	1.03
			$Q_{114}(1)$ 0.84	1.26
		$Q_{12}(2)$ 0.50	$Q_{121}(3)$ 0.21	0.92
			$Q_{122}(2)$ 0.50	1.21
			$Q_{123}(1)$ 0.79	1.50
		$Q_{13}(1)$ 0.79	$Q_{131}(2)$ 0.30	1.30
			$Q_{132}(1)$ 0.71	1.71
	⋮	⋮	⋮	⋮

Since we assume that the 3rd level scale is more important than the 1st and 2nd level scale, the level coefficients are 1,1 and 2.

Next, the relationship strength is determined by step 4. Here considered ECs are 9, EC1-EC9. Using PCMR, the relative demanded weight is not changed. The result is shown in table 3

Table 3. The relationship strength between QA and EC's

$Q_{M..}$	priority	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9
Q_{111}	0.58	.926 (1)	.500 (5)	.607 (4)	.713 (3)	.074 (9)	.287 (7)	.393 (6)	.819 (2)	.181 (8)
Q_{112}	0.81	.500 (5)	.713 (3)	.819 (2)	.926 (1)	.181 (8)	.393 (6)	.074 (9)	.287 (7)	.607 (4)
Q_{113}	1.03	.500 (5)	.819 (2)	.181 (8)	.607 (4)	.287 (7)	.926 (1)	.393 (6)	.713 (3)	.074 (9)
Q_{114}	1.26	.181 (8)	.926 (1)	.074 (9)	.819 (2)	.713 (3)	.287 (7)	.500 (5)	.393 (6)	.607 (4)
Q_{121}	0.92	.500 (5)	.713 (3)	.287 (7)	.393 (6)	.607 (4)	.819 (2)	.926 (1)	.074 (9)	.181 (8)
Q_{122}	1.21	.926 (1)	.819 (2)	.500 (5)	.074 (9)	.607 (4)	.287 (7)	.713 (3)	.393 (6)	.181 (8)
Q_{123}	1.50	.287 (7)	.819 (2)	.607 (4)	.926 (1)	.393 (6)	.713 (3)	.074 (9)	.500 (5)	.181 (8)
Q_{131}	1.30	.500 (5)	.607 (4)	.393 (6)	.181 (8)	.287 (7)	.819 (2)	.926 (1)	.713 (3)	.074 (9)
Q_{132}	1.71	.181 (8)	.713 (3)	.607 (4)	.074 (9)	.500 (5)	.287 (7)	.819 (2)	.926 (1)	.393 (6)
Q_{211}	1.01	.500 (5)	.607 (4)	.926 (1)	.393 (6)	.713 (3)	.287 (7)	.181 (8)	.074 (9)	.819 (2)
Q_{212}	1.30	.607 (4)	.819 (2)	.500 (5)	.181 (8)	.074 (9)	.713 (3)	.393 (6)	.287 (7)	.926 (1)
Q_{213}	1.59	.393 (6)	.926 (1)	.074 (9)	.500 (5)	.181 (8)	.819 (2)	.713 (3)	.607 (4)	.287 (7)
Q_{221}	1.59	.181 (8)	.819 (2)	.607 (4)	.287 (7)	.074 (9)	.713 (3)	.500 (5)	.393 (6)	.926 (1)
Q_{222}	2.00	.607 (4)	.713 (3)	.074 (9)	.287 (7)	.500 (5)	.393 (6)	.926 (1)	.819 (2)	.181 (8)
Q_{311}	1.30	.287 (7)	.819 (2)	.607 (4)	.713 (3)	.926 (1)	.181 (8)	.393 (6)	.500 (5)	.074 (9)
Q_{312}	1.59	.074 (9)	.926 (1)	.500 (5)	.607 (4)	.181 (8)	.393 (6)	.287 (7)	.713 (3)	.819 (2)
Q_{313}	1.88	.181 (8)	.926 (1)	.393 (6)	.819 (2)	.500 (5)	.287 (7)	.074 (9)	.713 (3)	.607 (4)
Q_{321}	1.88	.287 (7)	.926 (1)	.607 (4)	.393 (6)	.713 (3)	.181 (8)	.500 (5)	.074 (9)	.819 (2)
Q_{322}	2.29	.393 (6)	.819 (2)	.713 (3)	.926 (1)	.287 (7)	.607 (4)	.074 (9)	.500 (5)	.181 (8)
TIR_j		11.771	22.533	13.374	15.044	11.680	13.991	13.804	15.176	12.051
normalized_ TIR_j		.087	.163	.098	.110	.086	.103	.101	.111	.088

The next step is to calculate in order to obtain each EC's TIR. Now we evaluate the ECs' effectiveness against themselves. The result is shown in Table 4. The matrix effectiveness E is 9×9 square and the sum of a row 1. To find the value of steady-state(E^{∞}), E^{16} could be calculated.[7] The result is (0.0957 0.0198 0.0423 0.0183 0.1046 0.0119 0.4855 0.0293 0.1927).

Table 4 Effectiveness among EC's

	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9
EC1	0.4	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.2
EC2	0.0	0.7	0.0	0.2	0.0	0.0	0.0	0.0	0.1
EC3	0.2	0.0	0.3	0.0	0.1	0.0	0.0	0.3	0.1
EC4	0.0	0.1	0.0	0.4	0.0	0.1	0.0	0.2	0.2
EC5	0.1	0.0	0.1	0.0	0.5	0.0	0.1	0.0	0.2
EC6	0.0	0.1	0.0	0.1	0.0	0.6	0.0	0.1	0.1
EC7	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.2
EC8	0.0	0.1	0.0	0.2	0.0	0.1	0.0	0.4	0.2
EC9	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.2

Next, we could adjust the TIR on step 8. Here we obtain new TIR which satisfy customer needs more closely than the old. The table 5 is shown as comparing old TIR and new TIR.

Table 5 Comparison TIR's

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
old TIR	.087	.167	.099	.111	.086	.096	.102	.112	.089	.051
new TIR	.034	.166	.015	.178	.037	.068	.176	.097	.068	.159

4. Result and discussion

There are some remarkable features in the result. First, EC's which had high ranking(not just strong relationship strength) with the important QA's are high ranking in TIR. Second, EC which had been powerful to other EC's was varied from old TIR. Third, the infinitesimal difference of EC's were change to be remarkable, whether they had high relationship with important QA's and strong effectiveness.

In the conventional studies it is assumed that EC's are independent each other. But most of the practical problems are not independent. Therefore we analyzed each EC's effectiveness against EC's. Here we cannot concentrate only on one EC, i.e. we need to examine the impact of all the ECs on each of them by using limit probability. An example questions for the comparison may be : in considering EC1, which TC does contribute and how much? Similarly we repeat the same type of question for the other EC's.

5. Conclusion

The proposed methodology should be introduced to meet the VOC closely. Especially the roof of HOQ which the conventional studies have neglected is reflected to consider effectiveness among EC's. To prevent VOC priority and EC relationship strength from being distorted, PCMR and limit probability were used. But in this paper we ignored negative correlation. The proposed methodology could be used well in the various field, especially in case a part is the heart of a product, but related few QA's, i.e. the engine of a car.

Since the most of problems have negative correlations, it is evident that more work needs to be done in this area.

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