Development of QFD methodology

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Abstract. The production of elongated shaped charges is particularly dangerous (or in the language of ISO 9001 "special") and difficult from the point of view of quality control, so it is necessary to pay special attention to the dynamics of customer requirements, the level of development of competitors in order to remain a competitive organization. The proposed work addresses the issues of determining the ways of product development based on the analysis of the dynamics of consumer requirements and the level of competition, a mechanism is shown to identify bottlenecks of products based on the results of the organization's resource audits.

1. Introduction

A promising method for managing the quality of production of elongated shaped charges (ESC) is the method of structuring the quality function (QFD) over the life cycle stages of production [7].

In this paper, we propose approaches to improving the QFD methodology based on development (ESC), which will solve the following tasks:

I. Constantly monitor the level of demand,
II. Determine the relationship between customer requirements and characteristics (ESC),
III. Analyze the quality level of competitors' products,
IV. Determine the direction of development (ESC), based on an analysis of customer requirements and/or the position of the organization on the market,
V. Identify bottlenecks in the production process (ESC) associated with the level of quality of existing resources in the enterprise,
VI. Form requirements for products of outsourcer and / or supplier.

Fundamentals of QFD (in some sources referred to as "the deployment of quality functions"), the reader can find in almost all textbooks on quality management issues [2, 16, 17-21]. In this paper, we propose an improved model of its application that takes into account modern trends in quality management systems (one of which is the involvement of high-class specialists by outsourcing part of the production process to outsourcers) [1]. The tasks of tracking the dynamics of demand and determining the relationship between customer requirements and product characteristics have already been resolved (tasks 1 and 2) [3, 4]. Naturally, some of the characteristics of the manufacturer's products (ESC) are purchased, then it becomes necessary to build a Quality House of the supplier (outsourcer) [22, 23]. When applying QFD analysis technology from the constructed Quality House, the relationship between customer requirements and product characteristics is known [5]. From here you can calculate the degree of influence of outsourcer products on customer satisfaction:
\[
B_{\text{out}} = \frac{R \sum_{I} \text{I}_{\text{out}}}{R \sum_{I}} = \frac{\sum_{I} \text{I}_{\text{out}}}{\sum_{I}},
\]

(1)

Where \( B_{\text{out}} \) – the degree of influence of outsourcer products on the fulfillment of customer requirements;

\( R \) – the absolute weight of the requirement;

\( \sum_{I} \) – the relationship between demand and product characteristics (\( \bigtriangleup \) - 1; \( \bigcirc \) - 3; \( \bullet \) - 9);

\( \sum_{I_{\text{out}}} \) – the relationship between the user’s demand and the characteristics of the outsourcer's products.

The sum of the degrees of influence of the producer and outsourcer on the satisfaction of the consumer is equal to unity, then:

\[
P_{\text{out}} = 1 - B_{\text{out}},
\]

(2)

where \( P_{\text{out}} \) – the degree of influence of the producer's products on the fulfillment of the customer's requirements;

\( B_{\text{out}} \) – the degree of influence of outsourcer products on the fulfillment of customer requirements.

Assume that, as a result of interaction with the consumer, the level of fulfillment of the requirement [6], which is equal to \( Q \), was determined, then the loss level is equal to:

\[
Y_{\text{loss}} = 1 - Q.
\]

(3)

Then it can be argued that the losses (expressed in fractions) through the fault of the outsourcer were:

\[
P_{\text{out}} = B_{\text{out}} \cdot Y_{\text{loss}},
\]

(4)

where \( B_{\text{out}} \) – the influence degree of outsourcer products on the fulfillment of customer requirements;

\( Y_{\text{loss}} \) – level of loss or degree of customer satisfaction.

2. Development of the QFD-analysis method

This assumption is acceptable if the links between requirements and characteristics are constantly updated, which will make it possible to assert that the losses in the level of satisfaction are distributed by the consumer in such a way that the dissatisfaction with the corresponding characteristic increases the degree of its importance.

Accordingly, the satisfaction of the consumer with the output of the outsourcer will be:

\[
Y_{\text{Dout}} = 1 - P_{\text{out}}.
\]

(5)

Knowing the relationship between the products of the outsourcer and the manufacturer's products (by analyzing the "roof" of the Quality House), it is possible to determine the degree of the organization's dependence on the activity of the outsourcer and the weight of the outsourcer's products in meeting the customer's requirements [3, 15].

The development of the QFD-analysis method is possible by clarifying the absolute and relative weights of the product characteristics. When analyzing the consumer evaluation of products produced by the enterprise and its competitors, it is possible to carry out an accurate calculation of the absolute value of the product characteristic, knowing the degree of realization of the consumer's demand (column K table 1) and the weight of its importance (column B table 1).

The calculation of the absolute value of the importance of the product characteristics taking into account the consumer's opinion will be carried out as follows:

\[
B_{\text{char.coun.}} = \sum(I_{x} \cdot R_{x}) + \sum\left(\frac{P_{\text{lag}}}{T_{x}} \cdot (I_{x} \cdot R_{x})\right),
\]

(6)

where \( I_{x} \) – the relationship between demand and product characteristics (\( \bigtriangleup \) - 1; \( \bigcirc \) - 3; \( \bullet \) - 9);

\( R_{x} \) – the absolute weight of the requirement;

\( P_{\text{lag}} \) – lagging the consumer’s assessment of the extent to which the organization's requirement is being met from the target value;

\( T_{x} \) – the target value of the degree of realization of the customer's demand.

Calculation of the absolute value of the importance of the product characteristics taking into account the situation on the market will be performed as follows:
\[
B_{\text{char.coun.}} = \sum(I_x \cdot R_x) + \sum\left[C_{\text{lagg}}(I_x \cdot R_x)\right],
\]
where \(I_x\) – the relationship between demand and product characteristics (\(\bigtriangleup\) - 1; \(\bigcirc\) - 3; \(\blacklozenge\) - 9); \(R_x\) – the absolute weight of claim; \(C_{\text{lagg}}\) – lagging of the consumer's assessment of the degree of realization of the requirement of the organization in question from the maximum valuation in the market; \(P_x\) – the maximum value of the consumer's assessment of the degree to which the requirement is met in the market.

Table 1. Development of the QFD-analysis method.

| Customer Requirements | Absolute weight requirement | Product Features |
|-----------------------|---------------------------|-----------------|
|                       |                           | \(l\)           | \(n\) | \(l\) | \(m\) |
| \(A\)                 | \(B\)                     | \(C\)           | \(D\) | \(E\) | \(F\) | \(G\) | \(H\) | \(I\) |
| Req1                  | X                         | \(\bigtriangleup\) | \(\bigcirc\) | \(\blacklozenge\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) |
| Req2                  | Y                         | \(\bigcirc\) | \(\bigtriangleup\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) |
| Req3                  | Z                         | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) |
| Req4                  | P                         | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) | \(\bigcirc\) |
| \(\ldots\)            | \(\ldots\)              | \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) |

Evaluation of the implementation requirements

| Competitors | \(I\) | \(II\) | \(III\) |
|-------------|-------|--------|---------|
| \(A\)       | \(B\) | \(C\)  | \(\ldots\) |
| Req1        | X     | \(I_{\text{req1}}\) | \(II_{\text{req1}}\) | \(III_{\text{req1}}\) |
| Req2        | Y     | \(I_{\text{req2}}\) | \(II_{\text{req2}}\) | \(III_{\text{req2}}\) |
| Req3        | Z     | \(I_{\text{req3}}\) | \(II_{\text{req3}}\) | \(III_{\text{req3}}\) |
| Req4        | P     | \(I_{\text{req4}}\) | \(II_{\text{req4}}\) | \(III_{\text{req4}}\) |
| \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) |

Customer Requirements | Absolute weight requirement | target | backlog | maximum | losses |
|-----------------------|---------------------------|--------|---------|---------|--------|
| \(A\)                 | \(B\)                     | \(C\)  | \(N\)   | \(O\)   | \(P\)  | \(Q\) |
| Req1                  | X                         | \(N\) | \(\text{The maximum possible estimate}\) | N-J | \(\text{max}(K,L,M)\) | P-J |
| Req2                  | Y                         |       | N-J     | \(\text{max}(K,L,M)\) | P-J |
| Req3                  | Z                         |       | N-J     | \(\text{max}(K,L,M)\) | P-J |
| Req4                  | P                         |       | N-J     | \(\text{max}(K,L,M)\) | P-J |
| \(\ldots\)            | \(\ldots\)              | \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) | \(\ldots\) |

Based on the results of the construction of the Quality House, the level of delay in the degree of realization of the consumer's demand from the maximum score becomes known (column \(P\) Table 1) [5]. Suppose that this lag is related to the work of a particular resource, which participates in the production of relevant characteristics. Then, by determining (for example, based on the expert method or regression analysis) the degree of participation ("the share of resources used" in table 2) of each
resource in the production of the relevant characteristic, we calculate the level of claims and / or the quality level of the resource based on the consumer's opinion ("consumer votes").

Table 2. The relationship of characteristics with resources

| Product Features | 1 | ... | n | 1 | ... | m |
|------------------|---|-----|---|---|-----|---|
| resources        | D | E   | F | G | H   | I |
| Share of resources used | 0,5 | 0,2 | 0,8 | 0,3 | 0,4 |
| Res.1            | 1 |     |   |   |     |   |
| Res.2            | 0,5 | 0,8 | 0,5 |   |     |   |
| Res.3            | 1 |     |   |   |     |   |
| Σ                | 1 | 1   | 1 | 1 | 1   | 1 |

We will carry out calculations for resource Res.3 (Table 2). This resource is involved in the production of three characteristics (columns D, F, H), then the resource affects the fulfillment of the customer's requirements, respectively, Req1, Req2, Req4 - through the characteristic on the column "D"; Req 2 - on the column "F"; Req 1 - on the column "H". We will assume that the estimates of the implementation of requirements were distributed as follows:
- Req1 - 10 points out of 10 possible;
- Req2 - 8 points out of 10 possible;
- Req4 - 9 points out of 10 possible.

Let us determine the degree of participation of the resource in the realization of the requirement through characteristics (the matrix of communication requirements and characteristics). Reg2 is related to the characteristics in the columns "D", "F", "H", respectively, to "3", "1" and "3" points, Res.3 resource is involved only in the formation of "D" and "F" , Therefore, then the degree of influence of the characteristics on the demand will be respectively 3/7; 1/7; and 3/7. The degree of participation of the resource in the production of these characteristics according to Table 2 0.5; 0.8 and 0, respectively. Then the level of quality of the resource "Res.3" in the implementation of the requirement of Req2 is:

\[
1 - (0.5 \cdot \frac{3}{7} + 0.8 \cdot \frac{1}{7} \cdot \frac{10-8}{10}) = 0.934
\]

or in alphabetical order:

\[
Y_{qr} = 1 - \Sigma \text{(degrees} \cdot \frac{T_x}{\Sigma T_x}) \cdot \left(\frac{P_{lagg}}{T_x}\right),
\]

where degrees is the degree of resource participation ("share of resources used" in Table 2).

Having calculated all the values of Y_{qr}, it is possible to determine the average value and root-mean-square deviation of the quality level of the resource (and these calculations were obtained by analyzing the "consumer's voice"). Using the same approach, it is possible, knowing the levels of resource quality (established, for example, based on the results of audits, self-assessment, analysis of the level of defectiveness, etc.), to determine delays in the degree of realization of customers' requirements.

3. Result

As shown, the development of the method requires additional analyzes and calculations, and, consequently, the decision to improve production processes and / or design. Therefore, it is necessary to assess the adequacy of the constructed Quality House. Such an assessment is proposed as follows:

When the columns "J", "K", "L" are received, you can calculate the probability of product sales and compare this value with the sales figures;

Calculating the mean and standard deviation of Y_{qr}, you can compare these data with the actual level of quality of resources (established, for example, based on the results of audits, self-assessment, analysis of the level of defectiveness, etc.). Coincidence of the results of calculations will indicate the adequacy of the application of quality management methods.
But it should be remembered that the consumer's opinion differs from the manufacturer's opinion.

Acknowledgments
The paper is based on the financial support of the Council on Grants of the President of the Russian Federation (Project No. MK-3229.2018.8 "Improving the Standardization Management Method").
Peter the Great St. Petersburg Polytechnic University and the grant from the Program Competitiveness Enhancement of Peter the Great St.Petersburg Polytechnic University, Project 5-100-2020.

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