Analyzing Product Attributes using Logical Framework of Quality Function Deployment (Phase I): Concept and Application

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Abstract

Quality function deployment (QFD) is a customer-driven quality management, product and service development system for achieving higher customer satisfaction. This paper suggest a six step model for House of Quality (HOQ), the first and most important phase of QFD, the outcome of which is prioritized Voice of Customers (VOCs) that can be calculated with the help of Relative importance of customers, Customer competitive analysis and Improvement Ratios. In the proposed model, a 9 point scale is used to measure the voice of customers (VOCs) and their relative importance. The customer competitive analysis is conducted and the probabilities of each VOC for all the competitors are considered to assess the standing of each competitor vis-à-vis individual VOC. Normalization of VOCs has been done using mathematical formulae. A thorough explanation is given to understand the concept and applicability of the model to a Sauce manufacturing company. Without loss of generality the proposed model can be used to get the prioritized VOCs for any product.

1. Introduction

Dynamic business environment emphasizes the need to understand different decisions and practices for a firm to improve its competitive position. In view of diverse and dynamically changing scenario, customers' expectations have become more important for the companies. In this paper an attempt has been made to develop a model for planning matrix of the HOQ. This paper also presents a systematic approach to the QFD process. An illustrative study and analysis has been carried out to explain the application of the proposed model. Chan[1] (2004) has proposed a systematic approach to Quality Function Deployment. A firm has to continuously follow the customers' expectations and try to make the changes in the product to provide maximum customer satisfaction. Quality Function Deployment (QFD) has gained extensive support for product planning and development decisions.

2. QFD STEPS and OVRVIEW

Akao, Y. [2] has mentioned that QFD is a widely used customer – driven design and manufacturing tool originated in Japan in the late 1960. Conversion of Voice of customers into Technical parameters (TR) of the product to get the maximum customer satisfaction within the limited resources is the objective of QFD. Hauser J.R.[3] (1988) indicates that QFD utilizes four sets of matrices called House of Quality (HOQ) to relate Voice of Customers (VOC) to product planning, part deployment, process planning and manufacturing operations. The QFD system has been divided into four phases, each phase's important outputs, generated from the phase's inputs, are converted into the next phase as its inputs. So each phase can be described by a matrix of "WHATs" and "HOWs". Planning matrix of QFD has two principal parts: The customer portion and the Technical Portion [4]. The basic input of customer portion is Voice of Customers (VOC). VOC can be obtained by various methods like focus groups, questionnaire, interviews and customer survey etc. Most of VOC in HOQ process is generated from human beings' perceptions and linguistic assessments that are quite subjective and vague.

3. House of Quality Model (HOQ

The stages involved in HOQ model are detailed as below. Fig. 1 shows the block diagram of the model.

STEP I: The first step is to identify & collect the VOCs using any marketing survey method like Questionnaire, Focus Groups, Individual Interview, etc. In our study we have used Questionnaire survey

method to reach the customers. The VOCs collected using the method mentioned above can be grouped related into a category using Affinity Diagram (American Supplier Institute,[5] 1994; Bossert[6], J.L., 1991; Cohen, L. [7]1995). Griffin A.[8] (1993) has suggested a method of arranging random data into natural and logical groups can also be used.

STEP II: To determine the relative importance ratings of VOCs based on customers' perceptions.Suppose that through appropriate ways, K customers have been selected and M VOCs are denoted as $V_1, V_2, \ldots\ldots V_M$. The Relative Weightages of VOCs can be obtained by using the 5 point scale of importance shown in scale (1) based on the data collected from the customers (Elmore P.E.,[9] 1975; Miller G.A.,[10] 1965; Olsson U[11]., 1979).

I------I------II------I-----II-----I------II-----I--------II (1)

1 2 3 4 5 6 7 8 9

very low low moderate high very high

The relative perceptions of customers for all the VOCs are shown by scale (1). The relative importance of VOC can be expressed in the matrix form as below.Let for the VOC V_M, customer K allocates a relative importance rating g_{mk}, as shown in matrix **A**:

$$g_k = (1/m) \sum_{m=1}^{M} g_{mk}$$

where m = 1,2,3,-------M & k= 1,2,3,-------K. ----- (2)

g_g is the global average which signifies the average of perceptions of all the customers K with respect to all the VOCs (V_M).It can be calculated using equation (3).

$$g_g = (1/MK) \sum_{M} \sum_{K} g_{mk} \quad \text{----------(3)}$$

where k = 1,2,3,-------K

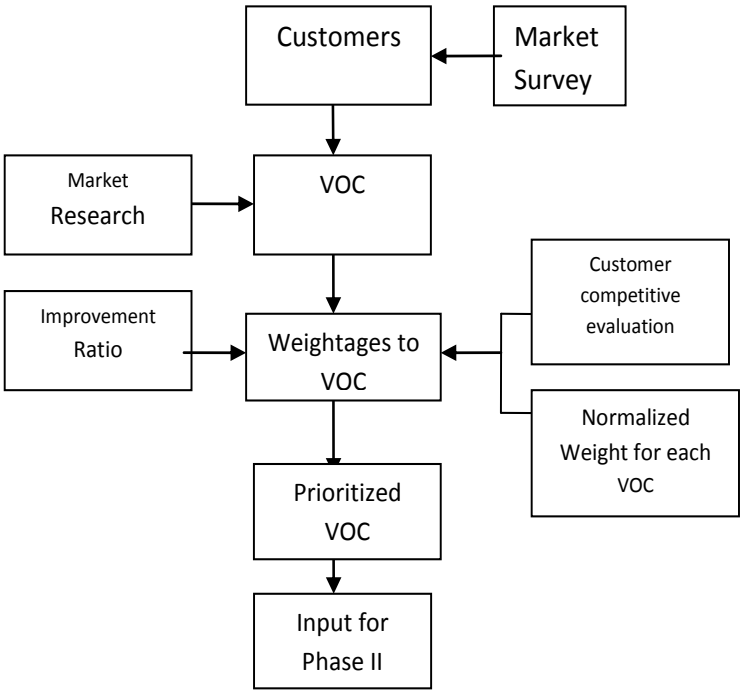

Fig. 1: Proposed Model

$$g_{mk} = \begin{array}{c} \\ V_1 \\ V_2 \\ V_3 \\ -V_M \end{array} \begin{array}{c} K_1 \quad K_2 \ldots\ldots\ldots K_k \\ g_{11} \quad g_{12} \ldots\ldots\ldots g1k \\ g_{21} \quad g_{22} \ldots \ldots\ldots g_{2k} \\ g_{31} \quad g_{32} \ldots\ldots\ldots\ldots g_{3k} \\ g_{m1} \quad g_{m2} \quad\quad g_{mk} \end{array} \text{-------- (A)}$$

Relative Normalized rating for V_M can be calculated from equation (1)

$$V_m = (1/k) \sum_{k=1}^{K} (g_{mk} / g_k) * g_g \quad m = 1,2,3, \ldots M. \quad \text{----- (1)}$$

Where g_k is the average of individual VOC for K customers can be calculated using equation (2).

Equation (1) on simplification gives normalized relative importance weights for each VOC and can be represented by vector **V.**

$$\mathbf{V} = (V_1, V_2, V_3 \ldots V_M)$$

SETP III:

The next step is to conduct Customer Competitive Analysis. The customers' perceptions regarding each VOC have been taken and the customers compare each brand with respect to different VOC. This customer competitive analysis can be shown in matrix **B.** Suppose there are L brands operating in the business. Let C_1 be our brand. Customer **K** supplies a rating x_{mk} on company C_l's performance in terms of V_M using scale (1). The performance rating of all the companies C_L on VOCs, V_M can be represented separately in the matrix form **(B).**

$$X = \begin{array}{c} \\ V_1 \\ V_2 \\ V_M \end{array} \begin{array}{c} \begin{array}{cccc} K_1 & K_2 \ldots\ldots & K_K \end{array} \\ \begin{pmatrix} x_{1l} & x_{12} \ldots\ldots\ldots & x_{1k} \\ x_{2l} & x_{22} \ldots\ldots\ldots\ldots & x_{2k} \\ x_{ml} & x_{m2} & x_{mk} \end{pmatrix} \end{array} \quad \text{-----(B)}$$

The normalized importance rating (I_R) of company C_L can be obtained using equation (4)

$$I_R = 1/k \sum_{k=1}^{K} (x_{mk} / x_k) * x_g \quad \text{----------(4)}$$

where m = 1,2,3, …… M

Where $x_{k\,is}$ the average of individual VOC for company in concern given by K customers can be calculated using equation (5). x_g is Global average of the importance rating of all the VOC for Companies. x_g can be evaluated using equation (6)

$$x_k = (1/m) \sum_{m=1}^{M} x_{mk} \quad \text{----------(5)}$$

where m = 1,2,3,-------M & k= 1,2,3,----K.

$$x_g = (1/MK) \sum_{m=1}^{M} \sum_{k=1}^{K} g_{mk} \quad \text{where k = 1,2,3,-------K. ---(6)}$$

The normalized importance rating I_R of all the companies can be shown in matrix **(C).**

$$I_R = \begin{array}{c} \\ V_1 \\ V_2 \\ V_M \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 \ldots\ldots & C_L \end{array} \\ \begin{pmatrix} I_{Rl1} & I_{Rl2} \ldots & I_{R1L} \\ I_{R2l} & I_{R22\ldots\ldots} & I_{R2L} \\ I_{Rml} & I_{Rm2} & I_{Rml} \end{pmatrix} \end{array} \quad \text{-- (C)}$$

The normalized customer competitive matrix will give the relative competitive states of all the competitors with respect to each VOC. This will provide information of each company's position for all VOC. The normalized importance in the matrix shows the standing of each company for each VOC. The probabilities corresponding to different VOCs for individual company can be calculated. The company which has highest probability for a particular VOC specifies the competitive advantage in terms of that VOC. The company which has the least probability in a particular VOC signifies the need/scope for improvement in that VOC. The probabilities for each VOC for focused company are calculated with respect to competitors.For the final importance rating on customer competitive analysis more weightage has to be assigned to that VOC which has got least probability. Prioritization of VOC can be done by calculating the inverse of probabilities for each VOC. The VOC which has the highest value will be on the top Priority. The inverse of Probabilities of company in concerned with respect to all VOCs and competitors can be denoted by a vector C_P.

$$\mathbf{C_P = (C_{P1}, C_{P2}, C_{P3}, \text{---------- } C_{PM})}$$

Where C_{P1}, C_{P2} etc are the inverse probabilities of each VOC for company in concern.

SETP IV: This step determines the company on concern's current Performance Goal. The performance goal for all the VOC can be set. These goals can be set realistically by the company which is the outcome of many managerial decisions. Assume that for $V_{M,}$ a proper performance goal **(a_m)** has been set using scale (1). Thus the Company has a Goal Performance vector in terms of the VOCs denoted as **a**.

$$\mathbf{a = (a_1, a_2, a_3, \ldots\ldots\ldots a_m)}$$

Each goal performance level should not be lower than current performance level. The improvement ratio for V_M can be denoted by U_M. The U_M can be calculated by equation (7).

$$U_M = a_m / x_{m1} \quad \text{---------- (7)}$$

The improvement ratios can be denoted by vector U.

$$\mathbf{U = (u_1, u_2 \ldots u_m)}$$

STEP V: The next step is to determine the importance ratings of all VOCs. The final importance rating of VOC for the company in concern can be a simple summation of relative importance (V), Competitive Probability (C_P) and improvement Ratio (U). The final Importance Rating of VOC is denoted by F , and can be calculated by equation (8).

$$\mathbf{F = (V + C_P + U)} \quad \text{---------- (8)}$$

On simplifying the equation (8) the final importance weightage of each VOC can be determined and higher priority should be assigned to higher value of the importance weightages. The outcome of equation (8) will be the prioritized VOC.

4 ILLUSTRATIVE EXAMPLES

The model can be understood with the help of following illustration. Here a brand of a **Sauce** manufacturing company is selected to illustrate the concepts and computations. Sauce manufacturing company denoted as $\mathbf{C_1}$ wishes to improve the sales in the region in response to the competition.

STEP I: The first step for the company C_1 is to identify its target market. This can be done by using appropriate Market Research technique as discussed earlier. Here we assumed that the company has already identified its target market, for the illustrations purpose five customers been selected to conduct the HOQ analysis i.e. K= 5.

With the help of Focus Groups, interviews, questionnaire, etc these five customers identifies five Voice of Customers (VOCs) for the product under consideration, i.e., Sauce. These are: Packaging, Life, Viscosity, Colour and Taste.

STEP II: : All VOCs will not be perceived alike by all the customers. The K customers i.e. 5 are asked to give their perceptions on the relative importance of VOCs using scale 1. Table 1(a) shows the relative importance about the VOCs.

Table 1(a): Customers' perception on the Relative Importance

Voice of Customers	Customer(1) K_1	Customer(2) K_2	Customer(3) K_3	Customer(4) K_4	Customer(5) K_5
VOC_1	Moderate	High	High	Very High	Very High
VOC_2	High	Very High	Moderate	Very High	Moderate
VOC_3	Moderate	Moderate	Very High	High	Moderate
VOC_4	Low	High	Moderate	Moderate	Low
VOC_5	High	Very High	Low	Moderate	Low

The customers' perceptions on the relative importance are linguistics in nature and can be converted in to crisp numbers using scale 1. Table 1(b) shows the converted relative importance into crisp numbers.

Table 1(b): relative importance rating of the 5 VOCs based on the five customers

Voice of Customers	Customer(1) K_1	Customer(2) K_2	Customer(3) K_3	Customer(4) K_4	Customer(5) K_5
VOC_1	5	7	7	9	9
VOC_2	7	9	3	5	3
VOC_3	5	5	9	7	5
VOC_4	3	7	5	5	3
VOC_5	7	9	5	9	5

The normalized relative importance ratings for all the

VOCs i.e. V_M can be computed using equation 1 and 2.Equation (1) on simplification gives normalized relative importance weights for each VOC and can be represented by vector V.

$$V = (V_1, V_2, V_3 \ldots V_M), \text{ i.e.}$$

V= (7.55, 5.32, 6.1, 4.50, 6.93)

Step III: This step involves the customer competitive evaluation. The sauce manufacturing company C_1 has identified three major competitors i.e. C_2, C_3, C_4 each of which make similar type of sauce. In order to understand the sauce market and company's relative position in the market and to finally find out the priorities of the VOCs for further improvement, the Company C_1 asks five customers to asses' relative performance of its own brand with competitive brands.

The customer competitive analysis for four companies is shown in table 2(a-d).

Table 2(a): Customer competitive analysis for first company

Voice of Customers	Customer(1) K_1	Customer(2) K_2	Customer(3) K_3	Customer(4) K_4	Customer(5) K_5
VOC_1	3	5	5	9	9
VOC_2	5	1	3	5	7
VOC_3	5	3	5	5	7
VOC_4	3	1	5	7	7
VOC_5	1	5	3	5	5

Table 2(b): Customer competitive analysis

Voice of Customers	Customer(1) K_1	Customer(2) K_2	Customer (3)K_3	Customer(4) K_4	Customer(5) K_5
VOC_1	3	1	5	7	7
VOC_2	5	7	5	7	5
VOC_3	3	9	5	7	5
VOC_4	3	7	3	5	9
VOC_5	1	5	5	7	7

for second company

Table 2(c): Customer competitive analysis for third company

Voice of Customers	Customer(1) K_1	Customer(2) K_2	Customer(3) K_3	Customer(4) K_4	Customer(5) K_5
VOC_1	7	5	5	5	1
VOC_2	7	3	5	3	7
VOC_3	7	7	5	3	7
VOC_4	9	5	5	7	5
VOC_5	3	5	5	9	7

Table 2(d): Customer competitive analysis for fourth company

Voice of Customers	Customer(1) K_1	Customer(2) K_2	Customer(3) K_3	Customer(4) K_4	Customer(5) K_5
VOC_1	9	7	9	7	7
VOC_2	9	7	7	9	9
VOC_3	7	9	7	9	9
VOC_4	7	9	9	9	7
VOC_5	9	9	9	9	9

The normalized customer competitive evaluation for four companies by five customers can be obtained by equation 4, 5 and 6.The normalized customer competitive evaluation can be represented in normalized importance matrix as shown in table 3.

Table 3: Normalized Relative Importance Matrix

Voice of Customers	Company(1) C_1	Company(2) C_2	Company(3) C_3	Company(4) C_4
VOC_1	6.17	4.66	4.60	7.81
VOC_2	4.12	6.15	4.97	8.19
VOC_3	5.21	5.81	5.83	8.21
VOC_4	4.32	5.30	6.13	8.21
VOC_5	3.99	4.69	5.48	8.59

The normalized importance in the matrix shows the standing of each company for each VOC. The probabilities of each VOC for each company can be calculated & shown in Probability matrix (P) Table 4. The company which has highest probability in a particular VOC specifies the competitive advantage in that VOC for the company. The company which has the least probability in a particular VOC specifies the need/scope for improvement in that VOC. For the final importance rating on customer competitive analysis more weightage has to be assigned to that VOC which has got least probability. Our study is mainly for the company 1 i.e. C_1 therefore probabilities for each VOC for C_1 has to calculated with respect to competitors. The inverse of Probabilities of Company (C_1) our concern with respect to all VOC and competitors can be denoted by vector C_P i.e. first column of the Probability matrix.

Table 4: Probability Matrix

Voice of Customers	Company(1) C_1	Company(2) C_2	Company(3) C_3	Company(4) C_4
VOC_1	0.265	0.201	0.200	0.340
VOC_2	0.176	0.263	0.210	0.350
VOC_3	0.208	0.232	0.230	0.330
VOC_4	0.180	0.221	0.260	0.340
VOC_5	0.176	0.206	0.240	0.380

The inverse of the probabilities for company C_1 is represented by vector C_P.

$$C_P = (C_{P1}, C_{P2}, C_{P3}, C_{P4})$$

After calculating the inverse probabilities of each VOC for Company C_1 is.

$$Cp = (3.768, 5.689, 4.813, 5.548, 5.694)$$

STEP IV:

Based on the resources available and the relative performance of the four companies on 5 VOCs, company C_1 can set improving goals on each VOC to better satisfy the customer needs. C_1 decides the performance goals on the VOC using scale 1. The current performance of the company C_1 is decided on the basis of customer evaluation i.e. relative perceptions.Thus the Company C_1 has a Goal Performance vector in terms of the VOCs denoted as vector **a**. $\mathbf{a = (a_1, a_2, a_3 \ldots a_m)}$

This set of goals is shown table 5. It is noted all the goal performance level should be higher than C_1's current performance.

Table 5: Improvement Ratios

VOCs	A	X	U
VOC1	7	6.17	1.135
VOC2	5	4.12	1.214
VOC3	8	5.21	1.537
VOC4	5	4.32	1.158
VOC5	4	3.99	1.001

The improvement ratios can be denoted by vector U.

$$\mathbf{U = (u_1, u_2 \ldots u_m)}$$

The value of U can be calculated using equation 6, the result is:

$$U = (1.135, 1.214, 1.537, 1.158, 1.001)$$

Step V: The next step is to put the values of V, C_P and U in equation 7.

$$\mathbf{F = (V + C_P + U)}$$

On putting the values of V, C_P, U and normalizing the matrix. The normalized value of V, C_P and U will be used in equation 7 to get the final priority of VOC as shown in table 6.

Table 6: Normalized Values of V, C_P and U

VOCs	V	C_P	U
VOC1	3.060	5.109	0.778
VOC2	4.620	3.600	0.832
VOC3	3.909	4.271	1.053
VOC4	4.506	3.048	0.794
VOC5	4.624	4.691	0.686

The final weightages of each VOC obtained as shown below in table 7.

Table 7: Final Weightages of each VOC

VOCs	$V + C_P + U$
VOC1	8.947
VOC2	9.053
VOC3	9.233
VOC4	8.347
VOC5	10.002

The top priority will be assigned to the VOC bearing the highest weightage.

Table no. 8 shows the final Prioritized Voice of Customer for company 1.

Table 8: Final Prioritized Voice of Customers

VOICE OF CUSTOMERS	PRIORITY
VOC5 (TASTE)	I
VOC3 (COLOUR)	II
VOC4 (LIFE)	III
VOC1 (VISCOSITY)	IV
VOC2 (PACKAGING)	V

Table 8 indicates the priorities of the Voice of Customers for company 1, i.e. TASTE has to given on the Top Priority has to be assigned to Taste of the Sauce, the company has to improve the Taste of the sauce to deal with the competition, The company has to make the necessary changes in the Colour of the sauce as per the Voice of Customers, The company has to improve the Life of the Sauce so that it can be used for the long period. As it indicates in table 8 the VOC Viscosity and Packaging are at the fourth and fifth position respectively in the priority it means that the company is on a relatively advantageous position as compared to its competitors and no improvement is required in the short run for these two VOCs. The company has to make the strategies for the improvement in Taste, Colour and Life attributes of the sauce to gain the substantial market share in the region.

5. CONCLUSIONS

The proposed model gives the prioritized Voice of Customers required for the product as an outcome of the Planning Matrix of House of Quality. These prioritized VOCs will be an input for the Part Deployment phase of Quality Function Deployment. The second phase i.e. the parts Deployment phase of QFD will provide the necessary changes in the parts to deploy the required Voice of Customers. The Company can consider this Prioritized Voice of Customer as a criterion among other criteria to make the strategic decision of Product Modification or Selection of Target Market.

REFERENCES

[1]Chan Lai – Kow and Ming – Lu Wu (2004). "A systematic approach to quality function deployment with a full illustrative example," Elsevier, 33 (2), 119 – 139.

[2] Akao, Y. (1990). "Quality Function Deployment: Integrating Customer Requirements into Product Design (translated by Glenn Mazur)," Productivity Press, Cambridge, MA,

[3]Hauser J.R., Clausing D. (1988). "The House of Quality," Harvard Business Review May -June 63 – 73.

[4] Day Ronald G (1996). Quality Function Deployment, Linking a company with Its Customers, Tata McGraw- Hill Publishing Company Limited, ASQC Quality Press, 20.

[5] American Supplier Institute, (1994). Quality function deployment (service QFD): 3- day workshop. Dearborn, MI: ASI Press.

[6] Bossert, J.L., (1991). "Quality function Deployment: a practitioner's approach", ASQC Quality Press, Milwaukee, WI.

[7] Cohen, L. (1995). "Quality function deployment: how to make QFD work for you,"Addison- Wesley, Reading, MA.

[8] Griffin, A., and Hauser, J.R. (1993). "The voice of customer," Marketing Science 12 (1), 1- 27.

[9] Elmore, P.E., and Beggs, D.L. (1975). "Salience of concepts and commitment to extreme judgements in response pattern of teachers," Education 95 (4), 325- 334.

[10] Miller, G.A. (1965). "The magic number of seven, plus or minus two," Psychological Review 63, 81- 97.

[11]Olsson, U. (1979). "On the robustness of factor analysis against crude classification of the observations," Multivariate Behavioral Research 14, 485 – 500.