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Quality function deployment: Integrating comprehensive matrix and SWOT analysis for effective decision making

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Abstract

In this ever-changing business scenario, the manufacturing product industries have to be in position to recognize the ever changing pulse and demands of the market. Customer satisfaction and quality management has become a strategic issue for companies in the new millennium. Quality Function Deployment (QFD) literature suggests that building up the House of Quality (HoQ) is not a difficult task, however to analyze and interpret the information available is replete with a lot of uncertainty and presents less than optimal solutions. This paper attempts to address these twin issues of the Post-HoQ analysis and its interpretation through SWOT. The development and mechanics of QFD model is presumed to be known to the followers and the paper deals specifically with post-HoQ model through a well-defined and structured approach to comprehensive matrix analysis. The paper contributes a method for evaluating and analyzing the customer data and technical data in QFD as a function of the generation of useful information resulting in a better decision making process. The outcome of the study is a comprehensive solution which discusses post-matrix analysis through underlying concepts; requisite steps; information needed; and the computations involved. The applicability of the proposed model is demonstrated with an illustrative hypothetical example of a medical-care product - disposable syringe and needle.

Keywords: QFD; HoQ; SWOT; Prioritization; Decision making

1. Introduction: Quality Function Deployment

Quality Function Deployment is a systematic process for helping a business to focus on its priorities, investments and customers. It uses cross-functional teams to identify and resolve issues involved in providing products, processes, services and strategies to meet or exceed customer expectations [5]. QFD is an excellent strategic planning tool because it creates customer focused alignment in the planning process [11]. Basic Building Blocks of House of Quality - QFD are demonstrated in Figure 1.

QFD is an innovative approach bringing quality - as demanded by the customers - upstream into the product development process [1]. QFD is said to have been first proposed in Japan by Yoji Akao in 1966. However, it did not emerge as a viable and formalized approach to quality control in planning until 1972, when Akao developed a quality control chart previously introduced at the Kobe shipyard of Mitsubishi Heavy Industries and instituted the QFD quality tables [1]. QFD's introduction in the US is usually traced back to the publication of QFD and CWQC in Japan in Quality Progress in 1983, by Masao Kogure and Yoji Akao. QFDs first industrial applications in the US originated mainly in the automotive industry. Early users of QFD included the Ford Motor Company, Procter & Gamble and 3M Corporation, but many other US companies have also adopted it [18]. In Europe, the first symposium on QFD took place in 1992 in the UK, but companies like Philips Corporation have been reported to have worked with QFD since 1986 [9]. QFD has been in use in the manufacturing industry since 1987. Meanwhile, many authors have advocated it as a planning tool to help in the management of product/process development, subject

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to some adaptations to meet the specific requirements of the concerned industry. However, there are not many published applications of QFD in the improvement of product development processes, especially at an industrial level.

2. Comprehensive matrix analysis

In conventional implementation of QFD, after the collection and compilation of all the customer and technical data in the QFD Matrix i.e. after the preparation of horizontal table and vertical table - further analysis is usually done empirically and ignores the correlation triangle values of customer requirements and engineering characteristics. Limited resources, increased market competition and product complexity however demands more optimal solutions. A new approach is proposed to address the lacunas due to the uncertainties and lack of quantitative methods and tools. The paper attempts to provide a ready reckoner and reference to all of the followers and enthusiasts of QFD. The development and mechanics of QFD model are however not discussed, and can be referred to from a number of academic and non-academic sources. This is followed by quantification of findings as a basis for comprehensive matrix analysis and concludes with a SWOT analysis. The outcome of the study is a comprehensive solution which discusses post-matrix analysis through underlying concepts; requisite steps; information needed; and the computations involved. The following set of input list along with the notations is used in the process; the details are given with the help of a hypothetical case example of a medical-care product – Disposable Syringe and Needle (Refer to Figure 1 for the final QFD in between each step of building House of Quality). Collected customer data are as follows:

a. Customers Requirements [CR]: CR_1, CR_2, CR_3, …, CR_i , …, CR_m.

CR_i : i^{th} Customer Requirement; i = 1 to m and m is the number of customer requirements.

CR_i = {Cleanliness & Purity; Safe, Reliable & Efficient; Ease of Handling & Use; Cost of the Product; No Leakages (Air/Fluid); Right Size/Correct Volume; Proper Markings; Precise Movements; Safe & Convenient Packaging and Tamper Proof (No reuse)}.

b. Interrelationship among Customers Requirements [X]: X_{12}, X_{13}, X_{14},…, X_{iu},…, $X_{(m)(m-1)}$.

X_{iu}: Interrelationship of i^{th} customer requirement with u^{th} customer requirement; i = 1 to m-1 and u = 2 to m, for $i \neq u$; i and u are customer requirements.

For CR_1: Y_{1u} = {+, 0, -, 0, 0, 0, 0, +, ++}; $u = 2$ to 10.

c. Customers Importance Ratings [I]: I_{11}, I_{12}, I_{13},…, I_{ci}, …, I_{zm}.

I_{ci} : Customers importance ratings of c^{th} customer for i^{th} customer requirement.

$I_i = (\sum I_{ci}) / z$; I_i is the mean value of customer importance ratings for i^{th} customer requirement and z is the number of customers considered.

I_i = {4, 5, 3, 5, 3, 2, 1, 2, 3, 5}.

d. Customers Satisfaction Ratings [S]: S_{111}, S_{112}, S_{113}, …, S_{cik}, …., S_{zmf}.

S_{cik} : Satisfaction ratings of c^{th} customer for i^{th} customer requirement using k^{th} firm product; k = 1 to f and f is the number of firms / competitors (in this case, f = 3).

$S_{ik} = (\sum S_{cik}) / z$; S_{ik} is the mean of satisfaction rating of i^{th} Customer Requirement for k^{th} firm's product.

S_o = {3, 5, 2, 3, 2, 2, 1, 2, 2, 3}, Similarly for S_a and S_b.

e. Sales Point Ratings [P]: P_{11}, P_{12}, P_{13}, …, P_{iq}, …, P_{md}.

P_{iq} : The sales point ratings of i^{th} customer requirement by q^{th} seller/dealer; q = 1 to d and d is the number of sellers / dealers.

$P_i = (\sum P_{iq}) / d$; P_i is the mean value of sales point ratings for i^{th} customer requirement.

P_i = {2, 3, 1, 3, 2, 2, 1, 2, 2, 3}.

Collected technical data are also as follows:

a. Engineering Characteristics [EC]: EC_1, EC_2, EC_3, …, EC_j,…, EC_n.

EC_j: j^{th} engineering characteristics; j = 1 to n and n is the number of engineering characteristics.

EC_j = {Cleanliness; Sterility; Toxicity; Leakages; Graduation Scale; Volume Labeling; Self Destructive Packaging; Optimum Lubrication; Syringe Components and Needle Components}.

b. Interrelationship among Engineering Characteristics (Roof) [Y]: Y_{12}, Y_{23}, Y_{13}, …, Y_{jv}, …, $Y_{(n)(n-1)}$.

Y_{jv}: Interrelationship of j^{th} engineering characteristic with v^{th} engineering characteristic; j = 1 to n-1 and $v = 2$ to n, for $j \neq v$; j and v = 1 to n, for $j \neq v$ and j and v are engineering characteristics.

For EC_1: Y_{1v} = {++, ++, --, *0, 0,* +, *0, 0, 0*} and $v = 2$ to *10.*

c. Correlation between Customer Requirements and Engineering Characteristics [C].

C_{ij} : Correlation value between i^{th} customer requirement and j^{th} engineering characteristic.

For CR_1 and EC_1: C_{11} = {*5, 4, 0, 2, 0, 0, 0, 0, 2, 2*}.

2.1. Quantifying customers expectations

The quantification of customer expectations measures the customer perception of the product relative to the competition. Data collected from customers is used as a basis for comparison. Requirements are not always prioritized strictly based upon the importance which the customers attach to each requirement. Often, through QFD, one wants to adjust the priorities of the requirements to account for the amount of work required to improve the customers' perceptions. A number of factors can be incorporated to indicate where the organization thinks the competition is headed. In order to prioritize the customers requirements, the combined effect of customer importance ratings, the customer satisfaction ratings and the sales points generated through the sellers and the dealers should be considered. The following steps will illustrate these prioritization methods. All of these different methods of prioritization involve defining calculations with respect to collected and derived customer data associated with input list of customer requirements.

2.1.1. Expectation gap

Expectation Gap tells us the difference between the level of performance expected from the product by the customers through Customer Importance Ratings and the actual level of performance denoted by the Satisfaction Rating of the selected product. This parameter helps us in knowing the list of customer requirements with which the customer is less satisfied than they ought to be.

Expectation Gap [EG]: EG_1, EG_2, EG_3, …, EG_i, …, EG_m.

EG_i: Expectation gap of i^{th} customer requirement and $i = 1$ to m.

$EG_i = I_i - S_{ik}$.

For CR_1: $EG_1 = I_1 - S_{1o} = 4 - 3 = 1$. Similarly, others are EG_i = {*1, 0, 1, 2, 1, 0, 0, 0, 1, 2*}.

2.1.2. Performance gap

Performance Gap is the numerical difference between the maximum rating in customer satisfaction column and the customer satisfaction rating of the model under consideration. Negative value of this parameter is taken as zero.

Performance Gap = Max (Satisfaction Rating of All Models) - Satisfaction of Selected Model.

Performance Gap [PG]: PG_1, PG_2, PG_3,…, PG_{ik}, …, PG_{mf}.

PG_{ik}: Performance gap of i^{th} customer requirement for k^{th} firm.

PG_{ik} = Max ($S_{i1}, S_{i2}, S_{i3},\ldots,S_{if}$) - $S_{ik} = MS_i - S_{ik}$.

For CR$_1$: $PG_{1o} = MS_1 - S_{1o} = 4 - 3 = 1$. Similarly, others are PG_i = {*1, 0, 1, 2, 1, 0, 0, 0, 1, 2*}.

2.1.3. Goal

This indicates as to what level the organization is trying to achieve with regard to each and every need of the customers. The levels are again expressed on a Likert Scale of 1 to 5 were the level strived depends on the factors like Importance Rating or the Satisfaction Rating. In fact the Goal value is greater of the two. Goal denotes our future products.

Goal = Max [Importance Rating, Max (Customer Satisfaction Rating of *O, A, B, C* and *D*)].

Goals [G]: G_1, G_2, G_3, …, G_i,…,G_m.

G_i : Goal of i^{th} customer requirement.

MS_i : Maximum satisfaction rating of i^{th} customer requirement.

G_i = Max [I_i, Max ($S_{i1}, S_{i2}, S_{i3},\ldots,S_{if}$)]

= Max [I_i, MS_i].

For CR_1 : G_1 = Max [I_1, Max (S_{1o}, S_{1a}, S_{1b})]

= Max [4, Max (3, 4, 4)] = 4.

Similarly, others are G_i = {4, 5, 3, 5, 3, 3, 3, 3, 4, 5}.

2.1.4. Improvement factor

Improvement Factor is the change from present to future product and is an indication of the amount of work required to change the level of perceived performance.

Improvement Factor thus can be said to as the effort level needed to achieve our targeted goals. Higher the improvement factor, greater the effort; because of the gap between actual and the expected quality level. It is the ratio of the goal value to the customer satisfaction rating for the model under consideration.

Improvement Ratio = Goal / Customers Satisfaction Rating; $R_{ik} = G_i / S_{ik}$.

For CR_1: $R_{1o} = G_1 / S_{1o} = 4/3 = 1.33$. Similarly, others are R_i = {1.33, 1.00, 1.50, 1.67, 1.50, 1.50, 3.00, 1.50, 2.00, 1.67}.

2.1.5. Preliminary raw weights

Preliminary Raw Weight value signifies the overall importance of the customer requirements as regard the development of the product. Preliminary Raw Weight sums up the priority level for the design and the development personnel.

The more the preliminary raw weight, the higher the priority. This value indicates where the design team should focus attention in order to address what is important to the customers and where they have to do a lot of work.

Preliminary Raw Weight = Importance Rating × Sales Points × Improvement Ratio

Preliminary Raw Weight [PRW] = PRW_1, PRW_2, PRW_3, …, PRW_i, …, PRW_m.

$PRW_{ik} = I_i \times P_i \times R_{ik}$.

PRW_{ik}: Preliminary Raw Weight of i^{th} Customer Requirement for k^{th} Firm.

For CR_1: $PRW_{1o} = I_1 \times P_1 \times R_{1o} = I_1 \times P_1 \times R_{1o} = 4 \times 2 \times 1.33 = 10.67$. Similarly, others are PRW_i = {10.67, 15.00, 4.50, 25.00, 9.00, 6.00, 3.00, 6.00, 12.00, 25.00}.

2.1.6. Factoring in the interrelationship values of customer requirements triangle

In QFD studies, various customer requirements are always stated and included, but interrelationship with one another is hardly ever incorporated and even if depicted then is never ever brought into the tabulations of the final importance ratings of the customer requirements. One reason for this is the difficulty in obtaining the relevant data, although it could be expressed in symbolic manner using appropriate synergistic or detrimental scales. Interrelationships among the customer requirements require the QFD personnel to make a lot of pair-wise comparisons about the degree of association and also the direction to which these customer requirements are interrelated [2,8]. Also there are few, if any, acceptable methods to incorporate the interrelationship into the calculation of the final importance ratings of the customer requirements [14,16,21]. However, most of these methods adopt calculation procedures using weighted product of the relationship measures in the importance rating column, sales point column and improvement factor column, without considering the magnitude, direction and degree of association amongst all customer requirements [17,22]. In order to overcome the above problem, a new method for prioritizing customer requirements in QFD was proposed by the authors, which integrates the customer requirement correlation triangle values with preliminary raw weights [19]. The proposed method weighs the customer requirements more efficiently, as not only the relative importance ratings, sales points and improvement ratios of customer requirements are considered but the values and their degree of association in the correlation triangle are also factored-in. Through the method proposed in this study, the CR correlation triangle symbols are translated into numerical values, with this a discrete but exact solution is obtained and then the prioritization weights are computed by utilizing the preliminary value of raw weights.

Final Raw Weight [FRW] = FRW_1, FRW_2, FRW_3, …, FRW_i, …, FRW_m.

$NICR = [m (m - 1)] / 2$.

$NPRW_i = PRW_i / SPRW$, $i = 1$ to m.

$IRW_i = NPRW_i + \sum\{NPRW_i \ (1 + NPRW_u) \ X_{iu}\}$; for $i \neq u$.

$NIRW_i = IRW_i / SIRW$.

$FRW_i = NIRW_i \times SPRW$.

$NICR$: Number of Interrelationship among Customer Requirements.

X_{iu}: Interrelationship value between i^{th} customer requirement and u^{th} customer requirement.

$SPRW$: Sum of all Preliminary Raw Weight of Customer Requirements.

$NPRW$: Normalized Preliminary Raw Weight of Customer Requirements.

IRW: Intermediate Raw Weight of Customer Requirements.

$SIRW$: Sum of all Intermediate Raw Weight of Customer Requirements.

$NIRW$: Normalized Intermediate Raw Weight of Customer Requirements

For CR_1: $NICR = [m\ (m - 1)] / 2 = 10(10\text{-}1)/2 = 45.$

$SPRW = \sum PRW_i = 116.17.$

$X_{1u} = \{0, 1.25, 0, 0.50, 0, 0, 0, 0, 1.25, 1.50\}.$

$NPRW_1 = PRW_1 / SPRW = 10.67 / 116.17 = 0.09.$

$$
\begin{aligned}
IRW_1 &= NPRW_1 + \sum\{NPRW_1\ (1 + NPRW_u)\ X_{1u}\} \\
&= 0.09 + \{[0.09\ (1 + 0.13)\ 1.25] + 0 \\
&\quad + [0.09\ (1 + 0.22)\ 0.50] + 0 + 0 + 0 + 0 \\
&\quad + 0 + [0.09\ (1 + 0.10)\ 1.25] \\
&\quad + [0.09\ (1 + 0.22)\ 1.50]\} = 0.57.
\end{aligned}
$$

$NIRW_1 = IRW_1 / SIRW = 0.57 / 6.11 = 0.09.$

$FRW_1 = NIRW_1 \times SPRW = 0.09 \times 116.17 = 10.86.$

Similarly, others are $FRW_i = \{10.86, 24.77, 2.65, 18.51, 8.32, 5.80, 2.89, 3.88, 12.74, 25.74\}$.

2.1.7. Final raw weights and percent importance

The critical few identify requirements that are most important to customers. These requirement areas and the engineering characteristics which govern and provide these requirements need extra management attention in order to enable development of a successful product package. Percent Importance simply contains the final raw weight values translated into percentage values.

Percent Importance = $\%\ AGE = FRW / SPRW$.

For CR_1: Percent Importance$_1$ = $\%\ AGE_1 = FRW_1 / SPRW \times 100 = 10.86 / 116.17 = 9.35\ \%$. Similarly, others are $\%\ AGE_i = \{9.35, 21.32, 2.28, 15.94, 7.16, 4.99, 2.49, 3.34, 10.97, 22.16\}$.

2.2. Quantifying engineering characteristics

One of the prime reasons for using QFD is to develop a product which will excite the customer and get him / her to purchase the brand model. When the customer's perceptions are captured as to how well different products perform in the marketplace, it leads to better understanding of what is driving the purchase decision. This helps in determining what the market likes and dislikes. However, it's still dealing with customer perceptions and not actual performance. It's not necessarily learned as to what one should do to create the desired level of perceived performance. The quantification of engineering characteristics is similar to the external assessment but involves technical details of the product rather than customer requirements. In this step, competition products were compared in the light of customer requirements. Engineers and technical personnel provide the data for the technical benchmarking. Studying the competition gives valuable insight into market opportunities and aids in setting reasonable targets.

2.2.1. Relationship score matrix

Cell score is the integration of the correlation values between requirements and characteristics with final raw weights of customer requirements.

Cell Score [CS]: CS_{ij} - Cell score of i^{th} customer requirement and j^{th} engineering characteristic.

$CS_{ij} = C_{ij} \times FRW_i$

C_{ij} : Correlation value between i^{th} customer requirement and j^{th} engineering characteristic.

For CR_1 and EC_1: Cleanliness and purity and Cleanliness.

$CS_{11} = C_{11} \times FRW_1 = 5 \times 10.86 = 54.30.$

2.2.2. Preliminary priority score

In this step, we prioritize the values for the designed features and is done by using the following formula:

Preliminary Priority Score [PPS]: PPS_1, PPS_2, PPS_3, …, PPS_j, …, PPS_n.

$PPS_j = \sum CS_{ij}$.

PPS_j : Preliminary priority score of j^{th} engineering characteristic.

For EC_1: $PPS_1 = CS_{11} + CS_{21} + CS_{31} + CS_{41} + CS_{51}$

$+ CS_{61} + CS_{71} + CS_{81} + CS_{91} + CS_{101}$

$= (5 \times 10.86) + (4 \times 24.77) + 0$

$+ (2 \times 18.55) + 0 + 0 + 0 + 0$

$+ (2 \times 12.74) + (2 \times 25.74) = 267.38.$

Similarly, others are $PPS_i = \{267.38, 281.29, 270.43, 267.17, 40.93, 111.52, 392.86, 124.80, 247.90, 205.33\}$.

2.2.3. Factoring in the interrelationship values of engineering characteristics correlation triangle

The study of the available literature on various models and framework for QFD (suggests that most of the methodologies suffer from one of the major weaknesses) the relative lack of concrete and clear guidelines as to how one could adequately conceptualize, integrate and implement its roof phase.

Several methodologies have been worked out, but their validity and applicability to prioritize engineering characteristics remains inconclusive and also the implementation results and findings are scarce [3,4,7]. Most of these methods adopt calculation procedures using weighted sum of the relationship measures in the relationship matrix with relative weights of customer requirements in aggregation of the importance of engineering characteristics, without considering the magnitude and direction of relationship amongst all engineering characteristics [13,23,25]. More often than not QFD users simply use direct methods to obtain these final priority scores, ignoring the correlations among the customer requirements and among the engineering characteristics even if they are available [12,15].

In order to weigh in the interrelationships, the roof symbols are translated into mathematical values for each combination of engineering characteristic, a discrete but exact solution is obtained and then the prioritization values are computed by utilizing the preliminary priority scores [20].

For a target engineering characteristic, the approach determines its importance rating as linear combination of its correlations with other engineering characteristics weighted by the engineering characteristics' preliminary priority scores.

Final Priority Score [FPS]: FPS_1, FPS_2, FPS_3, …, FPS_j, …, FPS_n.

$NIEC = [n (n - 1)] / 2.$

$NPPS_i = PPS_i / SPPS$ for $j = 1$ to n.

$IPS_j = NPPS_j + \sum \{ NPPS_j \times (1 + NPPS_v) \times Y_{jv} \}$ for $j \neq v$.

$NIPS_j = IPS_j / SIPS.$

$FPS_j = NIPS_j \times SPPS.$

$NIEC$: Number of Interrelationship among Engineering Characteristics.

Y_{jv}: Interrelationship Value between j^{th} Engineering Characteristic and v^{th} engineering characteristic.

PPS: Preliminary Priority Score of Engineering Characteristics.

$SPPS$: Sum of all Preliminary Priority Score of Engineering Characteristics.

$NPPS$: Normalized Preliminary Priority Score of Engineering Characteristics.

IPS: Intermediate Priority Score of Engineering Characteristics

$SIPS$: Sum of all Intermediate Priority Score of Engineering Characteristics.

$NIPS$: Normalized Intermediate Priority Score of Engineering Characteristics.

For EC_1: $NIEC = [n\ (n - 1)] / 2 = 10\ (10 - 1) / 2 = 45.$

$SPPS = \sum FPS_j = 2209.62.$

$Y_{1v} = \{0, 1.50, 1.50, 0.25, 0, 0, 1.25, 0, 0, 0\}.$

$NPPS_1 = PPS_1 / SPPS = 267.38 / 2209.62 = 0.12.$

$IPS_1 = NPPS_1 + \sum \{ NPPS_1 \times (1 + NPPS_v) \times Y_{1v} \}$

$= 0.12 + \{[0.12 \times (1 + 0.13) \times 1.50]$

$+ [0.12 \times (1 + 0.12) \times 1.50] + [0.12 \times (1 + 0.12)$

$\times 0.25] + 0 + 0 + [0.12 \times (1 + 0.18) \times 1.25]$

$+ 0 + 0 + 0\} = 0.709.$

$NIPS_1 = IPS_1 / SIPS = 0.74 / 5.36 = 0.14.$

$FPS_1 = NIPS_1 \times SPPS = 0.14 \times 2209.62 = 305.60.$

Other $FPS_j = \{305.60, 348.61, 335.52, 308.79, 30.27, 81.48, 381.94, 82.06, 243.52, 91.94\}$.

2.2.4. Final priority scores and percent importance

The final priority score when sorted on their numeric values highlights the area on which the manufacturer should focus their attention. For carrying out these improvements the company needs to focus on the engineering characteristics with greater values of final priority scores. These are the engineering characteristics that the organization ‘O’ should be concentrating on. This will not only lead to better level of performance, but also give them an edge over their competitors as far as the customer satisfaction is concerned. The relationship between the final raw weight of the customer requirements and the priority scores of the engineering characteristics is such that as the organizations concentrates its efforts on the design measures and improves them to the target level, the customers’ needs are automatically taken care of. A little improvement in the performance of the organization in these respects, would overcome a number of weaknesses which will not only help the organization in competing better but also stand them in good stead as far as the expectations of customers are concerned. Thus, improving the product with respect to these engineering characteristics will be solving most of their problems. Because these considered engineering characteristics has a direct bearing on the disadvantages the manufacturer has vis-à-vis its competitors.

Percent Importance = $\%AGE = FPS / SPPS$.

For EC_1: $\% AGE_1 = FPS_1 / SFPS \times 100$

$$=305.60 / 2209.62 \times 100 = 13.83\ \% .$$

Other $\%AGE_J$ = {13.83, 15.78, 15.18, 13.97, 1.37, 3.69, 17.29, 3.71, 11.02, 4.16}.

All these elicited, collected and derived data (in qualitative and quantitative form) and the associated mathematical analysis of them gives the results in the form of Final Quality Deployment Function Matrix also known as House of Quality (due to its shape). Refer to Figure 2.

2.3. SWOT analysis

The information used to prioritize the customer requirements is some of the most interesting and important information collected during the QFD process. The results of the QFD project start to become apparent once the team begins to utilize SWOT Analysis [24] and sorts the data to look at it from many different perspectives. When implementing a SWOT analysis to devise a set of strategies, the following guidelines should be utilized.

2.3.1. Strengths

Determine organization's strong points. This should be from both internal and external customers. It pays to be as pragmatic as possible. The strength of the organization can be deciphered by sorting the following value columns in descending order: Customer Importance Rating, Customer Satisfaction Rating and Improvement Factor, while sorting the following columns in ascending order of their Final Raw Weight and Expectation Gap. The following points aid testing the strengths of the organization:

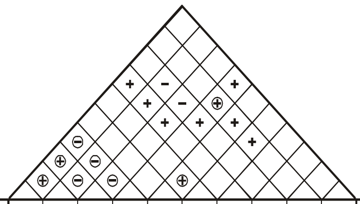
- Unique or distinct advantages that make the organization stand out the competition.
- Reasons that make the customers choose the organization over the competition.
- Core expertise area in products which your competition cannot imitate, at least for now.

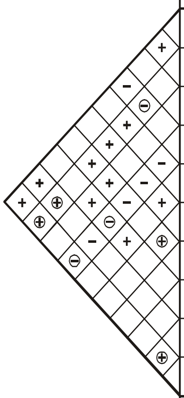
2.3.2. Weaknesses

Determine your organization's weaknesses, not only from technical point of view, but also more importantly, from the customers view point. Although it may be difficult for an organization to acknowledge its weaknesses, it is best to handle the bitter reality without procrastination. The weaknesses of the organization can be deciphered by sorting the following value columns in an ascending order:

Customer Importance Rating, Customer Satisfaction Rating and Improvement Factor, while sorting the following columns in a descending order of their Final Raw Weight and Expectation Gap. The following points aid in unraveling the weaknesses of the organization:

- Operations or procedures that have to be streamlined.
- Explore the Areas and Reasons in which competition operates better than your organization.
- Awareness and knowledge regarding the areas to be avoided - ‘no entry zones’.
- Market segment monopolized by the competition.





ENGINEERING CHARACTERISTICS / CUSTOMER REQUIREMENTS	Cleanliness Factor	Sterility Factor	Toxicity Factor	Leakage Factor	Graduation Scale	Volume Labeling	Self Destructive Packaging	Optimum Lubrication	Syringe Components	Needle Components	Customer Importance Ratings
Cleanliness & Purity	5	4	3				3				4
Safe, Reliable & Efficient	4	5	5	3		2	4	2			5
Ease of Handling & Use					3		5		4	4	3
Cost of the Product	2	2	2	4	1	1	3	2	5	5	5
No Leakages (Air/Fluid)				5					3	3	3
Right Size/Correct Volume						5			3		2
Proper Markings					5	5			2		1
Precise Movements									5		2
Safe & Convenient Packaging	2	2	2				5	3			3
Tamper Proof (No reuse possibility)	2	2	2	3			5		3	3	5
Preliminary Priority Scores	267.38	281.29	270.43	267.17	40.93	111.52	392.86	124.80	247.90	205.33	2209.6
Old Ranks	4	2	3	5	10	9	1	8	6	7	-
Normalised Preliminary Priority Scores	0.12	0.13	0.12	0.12	0.02	0.05	0.18	0.06	0.11	0.09	1.00
Intermediate Priority Scores	0.74	0.85	0.81	0.75	0.07	0.20	0.93	0.20	0.59	0.22	5.36
Normalised Intermediate Priority Scores	0.14	0.16	0.15	0.14	0.01	0.04	0.17	0.04	0.11	0.04	1.00
Final Priority Scores	305.50	348.61	335.52	308.79	30.27	81.48	381.94	82.06	243.62	91.94	2209.6
Final Priority Scores In Percentage	13.83	16.78	15.18	13.97	1.37	3.69	17.29	3.71	11.02	4.16	100.00
New Ranks	5	2	3	4	10	9	1	8	6	7	-

CUSTOMER REQUIREMENTS	Customer Satisfaction Ratings - O	Customer Satisfaction Ratings - A	Customer Satisfaction Ratings - B	Sales Points Rating	Maximum Customer Satisfaction	Expectation Gap - O	Performance Gap - O	Goal - O	Improvement Ratio - O	Preliminary Raw Weight - O	Old Ranks	Normalised Preliminary Raw Weight - O	Intermediate Raw Weight - O	Normalised Intermediate Raw Weight - O	Final Raw Weight - O	Final Raw Weight In Percentage - O	New Ranks
Cleanliness & Purity	3	4	4	2	4	1	1	4	1.33	10.67	5	0.09	0.57	0.09	10.86	9.35	5
Safe, Reliable & Efficient	5	4	3	3	5	0	0	5	1.00	15.00	3	0.13	1.30	0.21	24.77	21.32	2
Ease of Handling & Use	2	3	3	1	3	1	1	3	1.50	4.50	9	0.04	0.14	0.02	2.65	2.28	10
Cost of the Product	3	4	4	3	4	2	1	5	1.67	25.00	1	0.22	0.97	0.16	18.51	15.94	3
No Leakages (Air/Fluid)	2	3	3	2	3	1	1	3	1.50	9.00	6	0.08	0.44	0.07	8.32	7.16	6
Right Size/Correct Volume	2	2	3	2	3	0	1	3	1.50	6.00	7	0.06	0.30	0.05	5.80	4.99	7
Proper Markings	1	2	3	1	3	0	2	3	3.00	3.00	10	0.03	0.15	0.02	2.89	2.49	9
Precise Movements	2	2	3	2	3	0	1	3	1.50	6.00	7	0.06	0.20	0.03	3.88	3.34	8
Safe & Convenient Packaging	2	4	4	2	4	1	2	4	2.00	12.00	4	0.10	0.67	0.11	12.74	10.97	4
Tamper Proof (No reuse possibility)	3	4	5	3	5	2	2	5	1.67	25.00	1	0.22	1.35	0.22	25.74	22.16	1
										116.17	-	1.00	6.11	1.00	116.17	100.00	-

Figure 2. Quality Function Deployment - Final Matrix (House of Quality).

2.3.3. Opportunities

Another major factor is to determine how your organization can continue to grow within the marketplace. After all, opportunities are everywhere, such as changes in technology, government policy, social patterns, and so on. The opportunities of the organization can be garnered by sorting the following value columns in an ascending order: Goal and Sales Points, while sorting the following columns in a descending order of Final Priority Scores. The following points aid tapping up the opportunities in front of the organization:

- Always look out for and tap attractive opportunities within your marketplace.
- Awareness regarding any new emerging trends within the market.
- Predict and focus on the areas for the future that may depict new opportunities.

2.3.4. Threats

No one likes to think about threats, but we still have to face them, despite the fact that they are external factors that are out of our control. It is vital to be prepared and face threats even during turbulent situations. The threats faced by the organization can be understood by sorting the values column of Final Priority Score in a descending order, while sorting the value columns of Customer Satisfaction Rating and Performance Gap in an ascending order. The following points aid comprehending and predicting the threats faced by the organization:

- Strategies of the competition that is suppressing your organizational development.
- Changes in consumer demand, which call for incorporation of new features requirements.
- Alternative or modern technology hurting your organization's position within the marketplace.

The benefits of SWOT lie in matching specific internal and external factors, which creates a strategic matrix and makes sense. The internal factors are within the control of the organization, such as operations, finance, marketing, and in other areas. The external factors are out of your organization's control, such as political and economic factors, technology, competition, and in other areas.

The four combinations are:

- Maxi-Maxi (Strengths / Opportunities): This combination shows the organization's strengths and opportunities. In essence, an organization should strive to maximize its strengths to capitalize on new opportunities.
- Maxi-Mini (Strengths / Threats): This combination shows the organization's strengths in consideration of threats, e.g. from competitors. In essence, an organization should strive to use its strengths to parry or minimize threats.
- Mini-Maxi (Weakness / Opportunities): This combination shows the organization's weaknesses in tandem with opportunities. It is an exertion to conquer the organization's weaknesses by making the most out of any new opportunities.
- Mini-Mini (Weaknesses / Threats):This combination shows the organization's weaknesses by comparison with the current external threats. This is the most definitely defensive strategy, to minimize organizations' internal weaknesses and avoid external threats.

Having understood the QFD and SWOT philosophies, it is essential to identify how and in what ways these philosophies could be applied in business strategies. People in the organization have to face all kinds of competition. Competitors may come within the organizational constituents as well as individual constituents. Winning or losing in battle is very much based on how effectively they manipulate the perceptions and opinions of constituents. Those who have the most accurate and up-to-date information will win. Information helps the analysis process and decision making. The wisdom for the traditional competition can equally be applied in information competition.

3. Results and analysis

In order to carry out a full fledged comparative analysis of the outcome given by the QFD model, the first step is to segregate the necessary and crucial information pertaining to the 'critical-success- parameters' from the customer as well as technical point of view. Critical-success-parameters here refer to the customer requirements and engineering characteristics which are very vital and crucial for the success of the product. It is a recommended practice to focus and concentrate only on the critical success parameters; and is considered to be the top half of the sorted rank-order attributes on the basis of their percent importance weights. The Final QFD Matrix provides us with the final raw weights of each customer requirement and also final priority scores of each engineering characteristic. Carrying out a comparative analysis on the results provided by the Final QFD with SWOT on the final raw weights (customer data) and final priority scores (technical data), the following inferences can be drawn. Tables 1 and 2 show the weights and scores in a sorted rank order form.

Since it is beyond the scope of the paper to carry out the above discussed SWOT analysis (Section 2.3) on the obtained QFD results, only the final results of the analysis are given in Figure 3. The strengths and weaknesses pertains to the technical data influenced by internal assessment and market competitors; while the opportunity and threats pertains to the customer data influenced by the external assessment and performance factors in the market. As per the Final Matrix of QFD which tries to factor-in the correlation triangle values amongst customer requirements; the sorted values of customer requirement on final raw weights list out the critical-success-parameters presenting *opportunity* are as 'tamper proof (no reuse)', 'safe, reliable and efficient' and 'cost of the product'. Refer to Table 1. However, the apparent *threats* are from 'ease of handling and use', 'proper markings' and 'precise movements'.

On the similar lines, the critical success-parameters with regard to the technical design aspect of the syringe and needle can be interpreted from the absolute priority scores below the central relationship matrix in each of the columns. When investigated column wise as per the value of Final Priority Scores, the significance and contribution of each engineering characteristic in satisfying overall customer needs can be seen. As shown in Table 2, which depicts the magnitude of Final Priority Scores - calculated with the relationship cell values and final raw weights. The final output of the case has shown that, the engineering characteristics like 'self destructive packaging', 'sterility factor' and 'toxicity factor' are the highest contributors in the overall success of the product and also represent *strengths* of the organization. On the other hand, the technical *weaknesses* of the organization get exposed in the form of 'graduation scale', 'volume labeling' and 'optimum lubrication'. Refer to Table 2. The engineering characteristics highlighted by the sorted top ranked maximum priority scores are the true reflection of demanded quality characteristics not only from customer view point but also if judged through the values of final raw weights and the final importance ratings of each customer requirements. The top half of the ranked order customer requirements pertains to safety (no reuse and safe packaging), reliability (reliable and efficient) and cleanliness aspect of the syringe and needle representing *opportunity* and interestingly the top half of ranked order engineering characteristics are also direct representative of these customer requirements and justifiably pertains to the same demanded quality functions catered viz. safety (self destructing), reliability (sterility and leakage factor) and cleanliness (cleanliness and toxicity factor) aspect of the product representing *strength*. On the other hand, the bottom half of customer requirements pertain to performance (ease of handling and precise movements) and conformance (proper markings) aspects representing *threats*, and correspondingly the bottom half of the engineering characteristics directly relates with these requirements viz. performance (optimum lubrication) and conformance (correct scale and volume labeling) aspects representing the *weaknesses*. The engineering characteristic with higher importance weights in the form of final priority scores are governing the customer requirements with greater importance weights represented through the final raw weights. Thus the outcome manifests itself into a true representative of the all the important factors affecting and leading to the revision of importance weights of the customer needs. These SWOT influenced values of importance, their rankings and order are much more precise and accurate, leading to better and informative decision making.

4. Conclusion

QFD is a subjective, primarily a qualitative structured and systematic approach to document customer needs. It is a complex and time-consuming process, implementing QFD does not run smoothly and moreover, incorrect application of QFD results in increased work without accompanying benefits. In the available and accessible academic work on QFD there exists a host of discrepancies and contradictions. The studies are replete with diverse and inconsistent methods, concepts, and procedures. The quantitative approach adopted via raw customer weights and priority technical scores addresses the problem of subjective and qualitative analysis, thus allowing the design to be more quantitative and brings voice of the customer in the analysis. The proposed approach is conceptually sound and methodologically rigorous and attempts to expand knowledge by building on the existing theory and models.

Table 1. Sorted rank order final list of customer requirements.

RANK	CUSTOMER REQUIREMENTS	S. NO.	F R W	% AGE	% CUM
1	TAMPER PROOF (NO REUSE POSSIBILITY)	10	25.74	22.16	22.16
2	SAFE, RELIABLE & EFFICIENT	2	24.77	21.32	43.48
3	COST OF THE PRODUCT	4	18.51	15.94	59.42
4	SAFE & CONVENIENT PACKAGING	9	12.74	10.97	70.39
5	CLEANLINESS & PURITY	1	10.86	9.35	79.74
6	NO LEAKAGES (AIR/FLUID)	5	8.32	7.16	86.90
7	RIGHT SIZE/CORRECT VOLUME	6	5.80	4.99	91.89
8	PRECISE MOVEMENTS	8	3.88	3.34	95.23
9	PROPER MARKINGS	7	2.89	2.49	97.72
10	EASE OF HANDLING & USE	3	2.65	2.28	100.00
-	**COLUMN TOTAL**	-	116.17	100.00	-

Table 2. Sorted rank order final list of engineering characteristics.

RANK	ENGINEERING CHARACTERISTICS	S. NO.	F P S	% AGE	% CUM
1	SELF DESTRUCTIVE PACKAGING	7	381.94	17.29	17.29
2	STERILITY FACTOR	2	348.61	15.78	33.06
3	TOXICITY FACTOR	3	335.52	15.18	48.25
4	LEAKAGE FACTOR	4	308.79	13.97	62.22
5	CLEANLINESS FACTOR	1	305.50	13.83	76.05
6	SYRINGE COMPONENTS	9	243.52	11.02	87.07
7	NEEDLE COMPONENTS	10	91.94	4.16	91.23
8	OPTIMUM LUBRICATION	8	82.06	3.71	94.94
9	VOLUME LABELING	6	81.48	3.69	98.63
10	GRADUATION SCALE	5	30.27	1.37	100.00
-	**COLUMN TOTAL**	-	2209.62	100.00	-

	Strengths	**Opportunities**	
Strengths	• SELF DESTRUCTIVE • STERILITY FACTOR • TOXICITY FACTOR	• TAMPER PROOF (NO REUSE) • SAFE, RELIABLE & EFFICIENT • COST OF THE PRODUCT	**Opportunities**
Weaknesses	• OPTIMUM LUBRICATION • VOLUME LABELLING • GRADUATION SCALE	• PRECISE MOVEMENTS • PROPER MARKINGS • EASE OF HANDLING & USE	**Threats**
	Weaknesses	**Threats**	

Figure 3. Strength - weakness - opportunity - threats matrix.

The paper attempts to provide a ready reckoner and reference to all the followers and enthusiasts of QFD. The proposed methodology employs a new quantitative procedure to incorporate and factor-in the usually mentioned and computationally ignored correlation triangle values. All the underlying theories and concepts; information needed with data gathering techniques; computations involved; customer table; technical table; post-matrix analysis are clearly indicated to present a working framework for the users and practitioners to carry out QFD analysis. The model also suggests the use of more rationale post-matrix analysis to perform internal and external assessment and carried out SWOT analysis for better interpretation of available information for effective decision making. The authors welcome any constructive suggestions and criticism with regard to the reader's on-field expertise and experiences to enrich this model thus making the QFD analysis even more complete and comprehensive.

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