QUALITY FUNCTION DEPLOYMENT (QFD)

Introduction

Quality Function Deployment (QFD) was first put forth in 1966 in Quality Assurance work done by Prof. Yoji Akao and Mr. Oshiumi of Bridgestone Tire. Its purpose was to show the connections between true quality, quality characteristics, and process characteristics. This was done using the Fishbone Diagram, with true quality in the heads and quality and process characteristics in the bones. For more complex products, Mitsubishi Heavy Industry Kobe Shipyards combined these many fishbones into a matrix. In 1979, Mr. Sawada of Toyota Auto Body used the matrix in a reliability study which permitted him to address technical trade-offs in the quality characteristics. This was done by adding a "roof" to the top of the matrix, which he then dubbed the House of Quality (HOQ).

This manuscript presents an interactive tutorial on HOQ matrix, which is the most recognized form of QFD. It is utilized by a multidisciplinary team to translate a set of customer requirements (Voice of Customer), market research and technical benchmarking data into an appropriate number of prioritized engineering targets to be met by a new product design. HOQ is actually an assembly of other deployment hierarchies as shown in Fig. 1.

![Figure 1. HOQ structure.](image)

1. Customer Requirements (Quality Characteristics Hierarchy)
2. Planning Matrix (Quality Planning Table)
3. Technical Requirements (Demanded Quality Hierarchy)
4. Inter-relationships (Relationships Matrix)
5. Roof
6. Targets (Design Planning)

Construction of HOQ Matrix – A Case Study

The complete HOQ matrix for designing a new suit is given in Fig. 2. The desirable and functional design parameters are defined and the performance of our design is compared with other company’s product performances. The following sections explain the procedure for constructing this matrix.

Section 1 - Customer Requirements

This is generally the first and the most important portion of HOQ matrix to be completed. It documents a structured list of a product’s customer requirements described in their own words (i.e. voice of customer). This information is usually gathered through conversations with customers (surveys) in which they are encouraged to describe their needs and problems.

The list of requirements gathered in such an exercise must be structured before its entry into the matrix. The construction of “Affinity and Tree Diagrams” can be used for this purpose. To build an affinity diagram, each customer statement is written onto separate cards. These cards are then arranged into groups with perceived associations by QFD team (Fig. 3). From each group a title card is chosen which encapsulates the meaning contained within that group. This may require the making of a new title card.
### Figure 2. Complete HOQ matrix to deploy QFD.

### Figure 3. Gathering and grouping the customer needs.

A second grouping exercise can be used to sort these group title cards to identify higher level associations. These groups can also be allocated into titles which may again be sorted. The resulting group structure is illustrated in an Affinity Diagram in Fig. 4.
The completed affinity diagram can then be used as the basis of a tree diagram (Fig. 5). This is constructed from the top down with each level being considered in turn for errors and omissions. The result is a family tree type hierarchy of customer needs, which is documented in the customer requirement portion of HOQ matrix.

Section 2 - Planning Matrix

The planning matrix serves several purposes. Firstly, it quantifies the customers’ requirement priorities and their perceptions on the performance of existing products. Secondly, it allows these priorities to be adjusted based on the issues concerning the design team.
The measures used in this section are generally gathered from customers using a questionnaire. The first and the most important measure is the **Importance Weighting**. This figure quantifies the relative importance of each of the customer requirements (described in the first section of HOQ matrix) from the customer’s own perspective. This measure is often shown in a column alongside the customer requirement description in the left section of HOQ matrix.

A questionnaire is used to gather these importance weightings. The customer is asked to give an importance weighting for each documented requirement generally using a pre-defined scale. A better but more involved approach is to use Analytical Hierarchy Process (AHP). This method also utilizes a questionnaire, but offers the customer pairings of requirements to choose the most important one from this pair. These results are then interpreted into numerical weightings using a matrix (Fig. 6).

When combining questionnaire data gathered from a number of customers, care should be taken to ensure that only a single market segment is considered in HOQ matrix. In general, the importance weighting entered into the matrix will be the average from the sample gathered. If this sample includes differing segments this mean figure will not be any value to the product design team. Using a table of voice of customer is useful for identifying segments in an existing sample.

The second common component of the planning matrix provides a measure of the satisfaction of customer with available products (Fig. 7). They are asked to consider the performance of each of the existing products in fulfilling their specified requirements. As for the importance weighting, a questionnaire can allow the selection...
of a value based on a predefined scale or provide product pairs for consideration when AHP is utilized. This data is often illustrated graphically in the HOQ.

Other measures which are determined by the design team can also be included in the planning matrix:

- **Planned Performance Rating**: quantifies the design team’s desired performance of the envisaged product in satisfying each requirement.
- **Improvement Factor**: can then be calculated by subtracting the performance rating of the company’s existing product from its planned performance rating (i.e. the number of improvement points). After that, this difference is multiplied by an **Improvement Increment** (e.g. 0.2), and this is added to 1 to give the improvement factor.
- **Sales Point** (SP): can be used to add weight to those requirements which can be utilized to market the product (usually between 1 and 1.5).

These measures are combined with the customer’s importance weightings to calculate an overall weighting for each customer requirement as follows:

\[
\text{Improvement Factor} = ([\text{Planned Performance Rating}] - [\text{Current Performance Rating}]) \times [\text{Improvement Increment}] + 1 \\
\text{Overall Weighting} = [\text{Importance Weighting}] \times [\text{Improvement Factor}] \times [\text{Sales Point}] 
\]

Additional measures (e.g. environmental impact, competitor’s future action, etc.) can also be included where these are deemed useful by the team. Finally, an **Overall Weighting** for each requirement can be calculated and placed in the planning matrix as in Fig. 8.

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**Section 3 - Technical Requirements**

This section is also referred to as “the engineering characteristics” or “Voice of Company”. It describes the product in the terms of the company. This information is generated by QFD design team who identify all the measurable characteristics of the product which are related to meeting the specified customer requirements.
In the same way that customer requirements are analyzed and structured, affinity and tree diagrams are applied to interpret these product characteristics (see the customer requirement section of this tutorial for more details). An additional row is often included in this section to illustrate the direction of change in each of these variables, which is considered as an improvement in product performance (Fig. 9).

Figure 9. Indication of technical response fulfilling customer requirements.

**Section 4 - Inter-relationships Matrix**

This section forms the main body of HOQ matrix which can be very time consuming to complete. Its purpose is to translate the requirements as expressed by the customer into the technical characteristics of the product. Its structure is that of a standard two dimensional matrix with cells that relate to combinations of individual customer and technical requirements (Fig. 10).

Figure 10. Interrelationship between customer requirement and technical response.
It is the task of QFD team to identify where these interrelationships are significant. Each combination of customer and technical requirement is considered in turn by QFD team (e.g. how significant is padding thickness in satisfying comfortable when hanging?)

The level of interrelationship discerned is weighted usually on a four point scale (i.e. high: 9, medium: 3, low: 1, none: 0) and a symbol representing this level of interrelationship is entered into the matrix cell. Each level of interrelationship weighting is assigned to a score to be understood and agreed by the team before completing this matrix. The relative values of these weightings should be chosen to suit individual QFD project and may be varied later to study their impact on the QFD exercise’s conclusions.

**Section 5 - The Roof**

The triangular “roof” matrix is used to identify where the technical requirements characterizing the product support or impede each other. As in the interrelationship section, QFD team work through the cells in this roof matrix considering the pairings of corresponding technical requirements.

For each cell, this question is asked: **Does improving one requirement cause a deterioration or improvement in other technical requirements?** Where the answer is a deterioration, an engineering trade-off exists and a symbol is entered into the cell to represent this (usually a cross or “-“). Where improving one requirement automatically leads to an improvement in the other requirement, an alternative symbol is entered into the cell (usually a tick or “+”). Different levels of such positive or negative interaction (e.g. strong, medium, weak) can be indicated using different colored symbols (Fig. 11).

The information recorded in the roof matrix is useful to design team in several ways. It highlights where a focused design improvement could lead to a range of benefits for the product. It also focuses the attention on the negative relationships in the design. These can represent opportunities for developing innovative solutions in order to avoid the necessity for such compromises being made.
Section 6 - Target Table

This is the final section of HOQ matrix to be completed, and it summarizes the conclusions drawn from the data contained in the entire matrix and the team’s discussions. It is generally made up from three parts:

- **Technical Priorities** (Fig. 12): The relative importance of each technical requirement of the product in meeting the customer’s specified needs can be simply calculated from the weightings contained in the planning and interrelationship matrix sections. Each interrelationship weighting is multiplied by overall weighting from planning matrix. These values are then summed down the columns to give a priority score for each technical requirement.

![Figure 12. Calculation of technical priority.](image)

- **Competitive Benchmarking** (Fig. 13): Each technical requirement that has been identified as important characteristics of the product can be measured both for the company’s own existing product and the available competitive products. This illustrates the relative technical position of the existing product and helps to identify the target levels of performance to be achieved in a new product.

![Figure 13. Competitor benchmarking.](image)

- **Targets** (Fig. 14): The final output of HOQ matrix is a set of engineering target values to be met by the new product design. The process of building this matrix enables these targets to be set and prioritized based on an understanding of the customer needs, the competitions’ performance and the organization’s current performance. The QFD team now needs to pay attention to this information when deciding on these values.

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<th>mean standards</th>
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<th>webbing strength</th>
<th>no. of colors</th>
<th>no. of sizes</th>
<th>padding thickness</th>
<th>no. of buckles</th>
<th>no. of gear loops</th>
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<td>8mm</td>
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Further Processing after QFD

The procedure until here is not necessarily the end of QFD process. The output of this HOQ matrix can be utilized as the first stage of a four-part QFD process referred to as Clausing Four-Phase Model (Fig. 15). This continues the translation process using linked HOQ type matrices until production planning targets are developed. This approach allows the “Voice of the Customer” to drive the product development process right through to the setting of manufacturing equipment.

References

This document was adopted from: http://sixsigma123.blogspot.com/2007/04/quality-function-deployment-qfd.html
The flash version of this document can be found at: http://www.webeducate.net/qfd/qfd.html