QUALITY FUNCTION DEPLOYMENT

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ABSTRACT

In the cut-throat 1990s the key to survival for a business is a knowledge of customer needs. At the same time the utilisation of Quality Management principles are required for efficiency, productivity and the elimination of waste. Clearly, there is a need for a quantitative tool that can directly use the "voice of the customer".

Quality Function Deployment (QFD) is a simple yet visually powerful planning tool for ensuring that customer demands are accurately translated into relevant technical requirements and actions throughout each stage of product development.

This working paper will discuss the development of QFD and the use of statistical techniques within the QFD framework.
1. INTRODUCTION

Currently, there is considerable media attention on Australia's ability to compete successfully in international markets. The message is that if Australia fails to compete successfully in international markets, the outlook is bleak.

In recent years, the world has witnessed the astounding growth of Japanese market share. In the last forty years Japan has become an economic powerhouse, a far cry from the post World War II years when the nation had a reputation for making poor quality items.

This transformation may largely be attributed to a focus on Quality. The result has been a global revolution which has affected every facet of business. American and European companies have been forced to respond and Australia has found itself under threat in the international market.

The precarious position Australia is in was reinforced by a recent report by Eisen and Mulraney [4], who concluded that Total Quality Management practices have been adopted less comprehensively than was previously assumed. The report estimates that no more than 2.5% of the 44300 manufacturing companies on the Australian Bureau of Statistics Integrated Register Count would have successfully implemented quality management practices.

For Australian industries to succeed nationally and internationally requires competitiveness in both price and quality. Rather than extolling pessimistic
messages for the future, we should ask how is Australia to acquire this competitiveness?

Firstly, it requires knowing what the market wants and catering for those wants at a competitive price. Keen customer orientation is required for the former as well as the capacity to turn customer requirements into manufacturing performance. For the latter, efficiency, productivity and the elimination of waste on every front is needed. The appropriate utilisation of Quality Management principles will achieve these objectives.

Essentially, Quality Management focuses on the organisation as a series of individuals utilizing and raising the capacity of the individual. Individual development and responsibility is critical if there is to be a successful customer orientation achieved throughout the company. Before going any further, one myth should immediately be dispelled. Total Quality Management is not just common sense as is often stated. Principles that may appear obvious and simple, once understood, generally require a quantum shift in thinking.

The word or concept of "Quality" has become somewhat elusive and nebulous. In fact, one could say that Quality principles have evolved over three generations. Inspection, or quality control, was the focus of the first generation (from the 1920s to 1940s) and this grew into statistical process control which concentrated on preventing problems during the manufacturing process. In the late 1960s, there was a move towards design improvement - that is, designing quality into a product. In the cut-throat 1990s the main thrust is that the key to survival is a knowledge of customer needs.
The customer is a mixture of varying complexity, from individual to corporate. Despite the intuitive sense it makes to please the customer first, it is surprising how many organisations and their managers fail to recognise the impact of quality and customer satisfaction on profit.

Dr W. Edwards Deming has always emphasised the importance of the customer:

"The consumer is the most important part of the production line"

The Japanese have grasped this idea, but the message has become vague and clouded in Western industry. In Japanese companies, the customer's voice drives all activities, whereas in the US and Australia the executive's voice tends to prevail. Furthermore, Japanese companies concentrate more on what the customer likes and trying to exceed those wants as opposed to fixing what the customer does not like which is the tendency in Australia. That is, the Japanese put more effort into designing quality at the product development stage, while Australian and US companies put a greater emphasis on problem solving.

There are companies who regard customer feedback as "soft data" which they would prefer not to trust. Therefore, there is clearly a need for a quantitative measurement tool that can directly use the "voice of the customer".

One such mechanism for soliciting customer input and subsequent translation into manufacturing specifications is Quality Function Deployment (QFD), a technique which had its formal origins in the Kobe shipyards in 1972.
Quality Function Deployment is a simple yet flexible methodology for ensuring that customer demands are accurately translated into relevant technical requirements and actions throughout each stage of product development. One can trace a clear path from customer requirements at the start of product planning down to the most detailed instructions at the operating level. QFD deploys customers needs both horizontally and vertically throughout an organisation as opposed to other quality techniques which have just been deployed vertically throughout an organisation.

In the following section, the concept of Quality Function Deployment will be discussed in more detail.

2. QUALITY FUNCTION DEPLOYMENT

L.P Sullivan [16] provides an excellent summary definition of Quality Function Deployment:

Quality Function Deployment - an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (ie, marketing strategies, planning, product design and engineering, prototype evaluation, production process development production, sales). This concept is further broken down into "product quality deployment" and "deployment of the quality function".

Eureka and Ryan [5] make a very valid point concerning Quality Function Deployment. They stress QFD is a "visually powerful planning tool" rather than a quality tool (such as control charts). They also state Quality Function Deployment contains aspects of Value Engineering and marketing
An appealing feature of QFD is the team approach utilised, because the method integrates personnel from engineering, finance, marketing and human resources to contribute to the design of a product. QFD assists in building a sense of teamwork in which all employees work together to improve efficiency and meet customer needs.

Central to QFD is listening to the customer, understanding what the customer says and interpreting and translating what the customer says. It is vital that the members of the QFD team share a common understanding and knowledge of a product's objectives.

Fortuna [6] claims that Quality Function Deployment is aimed at detecting and solving quality problems at a much earlier stage than Statistical Process Control. It is the intention of Quality Function Deployment to get the product right from the outset. For a start, it is easier and less costly to correct a defect, or potential defect in a product at the design stage rather than downstream at the inspection stage.

Fortuna also claims that Quality Function Deployment addresses the necessity to initiate the product development process with clear objectives for a product. These objectives, or sales points, should be maintained throughout the process enabling the establishment of a competitive advantage for a company.

There are two generally accepted approaches to Quality Function Deployment, namely a four-phase approach recommended by Macabe [10] or the matrix of
matrices adopted by King [10]. A series of matrices - or quality tables - are used to translate the "voice of the customer" which is supposed to drive the process. The four-phase approach entails product planning, product design, process planning and process control planning.

The matrix of matrices approach comprises thirty matrices arranged in a larger matrix after which the approach is named. Each matrix details a specific aspect of the development process and one will also find the four-phase approach embedded in these thirty matrices.

Most of the literature however, tends to focus on the main matrix used in product planning and that is the House of Quality, which may be found in Appendix One. The House of Quality is also called the quality chart.

The Akao text [1] defines the quality chart as a graphic device that enables one to:

- analyze systematically the structure of the true or ultimate qualities demanded by customers in their own words.
- indicate the relationship between these demanded qualities and certain quality characteristics.
- convert customer demands into counterpart characteristics
- develop a design quality.

The first step in constructing the House of Quality is to obtain the "voice of the customer", or customer attributes. These are placed in the left hand side of the House of Quality. The attributes are phrases customers use to describe a product or product characteristics. The importance of obtaining accurate data about customers' wants and needs cannot be understated. A
company should not assume that it already knows everything about its customers. Customer attributes can be in the form of statements or questions.

Customer attributes are usually obtained from a variety of sources such as special customer opinion surveys, marketing research data, dealer input, focus groups (where a facilitator guides a small group of people through a series of prepared questions), interviews (face-to-face or telephone), complaints, warranty data, toll-free hotlines, field contacts (trade shows and service calls).

Undoubtedly, this is the most critical part of the process and it is usually the most difficult because the voice of the customer is used to determine a number of things. These include determining what customer needs are required in the product or service, the importance of each customer attribute, how well the company meets the customer needs and how well one’s competition meets those needs.

Accompanying these customer requirements is a rating, or degree of importance which covers the customer-expressed importance for the listed requirements. These ratings represent the areas of highest customer expectation and greatest interest. The literature varies as to what scale is appropriate for ranking these customer ratings. The most common is a one-to-nine scale, with nine indicating very important, although scales of one-to-five have sometimes been used.

On the right hand side of the House of Quality, one then details the customer perception of existing competing products and marketing
information. Ideally, the company wants to match or exceed its competition so these columns are used to see where one's own company stands relative to the competition. The information is obtained from media information, marketing feedback, surveys, sales and service organisations. The rating system in this case is a one-to-five scale, with five indicating strength in a particular customer requirement and this scale is common across the QFD literature. These ratings are also plotted in the extreme right column of the House of Quality as a visual means of identifying opportunities for improvement.

In this section of the House of Quality, there is a column called planned level, where the company will focus on matching or surpassing the competition on features of the product that will give the company a competitive edge.

The amount of improvement can be quantified in the neighbouring column to planned level called Improvement Ratio. The improvement ratio is defined as:

\[
\text{Improvement Ratio} = \frac{\text{Planned Level}}{\text{Current company rating}}
\]

The next stage is to list the sales point of each customer requirement. The sales points represent the advertisable characteristics to be emphasised for the product in any particular market segment. Symbols are commonly used, with values of 1.5 representing a major sales point, 1.2 representing a minor sales point and the value of 1 states that the requirement is not a sales point.
Sullivan [16] states that in order to ensure that what the company claims is in fact delivered, all company activities should be involved in selecting the relevant sales points. The selling points are based on the company's past performance in the particular requirement the priority attached to meeting this need as well as an associated cost necessary to incorporate it in the product.

The importance of each customer requirement is computed as follows:

\[
\text{Importance Weight} = \text{Degree of Improvement} \times \text{Sales Point Value} \\
\text{Importance Ratio}
\]

Often these importance weights are converted to percentages, or relative weights. The relative weights are used for selecting the key customer requirements on which to concentrate time and resources.

Technical requirements, or quality characteristics, are now listed along the top of the House of Quality. The design team usually lists those engineering characteristics that are likely to affect one or more of the customer attributes. The quality characteristics should describe the product or service in measurable terms and should directly affect the customer perceptions. Suggested target values or technical assessment to measure quality characteristics may be placed in the bottom of the House of Quality.

After listing the technical requirements, one must then develop a relationship matrix between the customer attributes and technical requirements. The relationship matrix enables one to identify if a technical requirement has any bearing on satisfying a customer requirement.
The relationship grid is filled with different symbols based on a 9-3-1 system, where 9 represents a strong association and 1 represents a weak relationship. The absence of symbols in the relationship grid indicates the design as it stands would have little chance of meeting particular customer requirements. Conflicting design requirements can also be identified from the relationship matrix.

The importance weight for a technical requirement is computed as follows:

\[
\text{Importance Weight} = (\text{Relationship Value}) \times (\text{Relative Weight})
\]

where relationship values are obtained from the relationship matrix (9, 3 or 1) and relative weights are obtained from the previous ranking of customer attributes.

The final step in constructing the House of Quality is the "roof", or the correlation matrix. Again symbols indicate the strength of correlations between strongly negative (given a value of -9) to strongly positive (given a value of +9).

Only those on the team with strong technical expertise should assist in developing this part of the chart. The correlation matrix indicates complementary and conflicting technical requirements as well as show where trade-offs are necessary. Team members will also be able to see how individual efforts with each technical requirement affect others.
3. ADVANTAGES AND DISADVANTAGES OF QUALITY FUNCTION DEPLOYMENT

In the GOAL/QPC Research report [7] the following benefits of using QFD are reported based on a survey of American and Japanese companies:

- Decreased start-up problems
- Competitive analysis became possible
- Control points clarified
- Effective communications between divisions
- Design intent carried through to manufacturing
- Fewer product/service changes
- Reduced product/service development time
- Lower start-up costs
- Greater clarity of organisational and program priorities
- Identification and resolution of conflicting requirements.

There are also several disadvantages associated with constructing the House of Quality:

- most companies lack established methods for translating customer demands throughout product development.
- there is the pitfall that the House of Quality matrices can become very large.

In reference to the second disadvantage listed above, if one has fifty customer attributes and forty technical requirements, for example, then there are potentially two thousand intersections to address in the relationship matrix.
King [10] makes similar remarks along these lines. He also states that there is also the disadvantage of communication breakdowns between divisions and the whole QFD study may lose its focus.

4. USE OF STATISTICAL METHODS IN QUALITY FUNCTION DEPLOYMENT

A motivation for pursuing QFD is that despite the emphasis placed on the customer, insufficient attention has been paid to the mechanisms whereby customers' inputs (corporate or individual) are sought and translated into manufacturing terms.

It has been stated that Quality Function Deployment seeks to integrate customer needs information with the engineering variables of the manufacturing process. In the 1992 Youden address, Lawton [11] stresses the need to make the House of Quality in more quantifiable. This is due to the fact that after team discussion (e.g. Manufacturing, Finance, Marketing and R&D groups) the process to link engineering variables and customer attributes essentially remains qualitative.

One tool that Lawton suggests to assist in quantifying the engineering portion of the product development process is experimental design, or design of experiments. In experimental design one can change or perturb the engineering variables and observe the changes in the engineering characteristics.

One can see which engineering variables most affect customer attributes and predict the magnitude and direction of the impact on customer attributes. However, it is important to keep in mind to use only those attributes which are truly important to the customer.
The potential use of design of experiments and Quality Function Deployment, along with Taguchi techniques is also discussed in Ross' article [12].

However, design of experiments does not detail the relative importance, consumer preference or perception, although it does provide data for the attributes and design variables chosen.

As a means of predicting customer preference, Lawton suggests implementing a multivariate technique called conjoint analysis which has largely been used in the marketing field. Most conjoint studies have previously involved new product design and the determination of the important features to include in a new product given some form of price considerations.

In a conjoint analysis study the customer is required to look at descriptions of a product or a prototype in which one or more features, or attributes, may be substantially altered. A matrix, which has sides defined as the levels of the attributes being paired, is then completed by the customer based on a combination from most preferred to least preferred. The alternative products are then ranked in order of preference.

The utility function for that particular customer is then derived from the ranked data. The utility function measures the sensitivity of customer perceptions and preference to changes in product features. Cost is usually an important consideration, so usually one chooses the best features that give the greatest gains in customer preference at the lowest cost.

In reference to the first disadvantage listed in the previous section, in
King's book [10] the author suggests, "the Saaty method of ranking is a useful substitute when you cannot survey customers". This Saaty method of ranking, or Analytic Hierarchy Process, is also mentioned in Akao's book [1], "Converting the demanded quality priorities into function priorities is important but it is also important to determine the priority of the functions themselves from a technical standpoint. The AHP should be used".

AHP has been found to be useful in situations where many interests are involved and a number of people participate in the judgement process.

Essentially, the Analytic Hierarchy Process is a theory of measurement. In decision making problems it assists one in describing the general decision operation by decomposing a complex problem into a multi-level hierarchic structure of objectives, criteria, subcriteria and alternatives.

A fundamental scale of relative magnitudes, expressed in units of dominance, is provided by AHP to represent judgements in the form of paired comparisons. A ratio scale of relative magnitudes expressed in units of priority is derived from each set of comparisons. The overall ratio scale of priorities is synthesised to obtain an overall ranking of the alternatives.

Introduced in 1977 by Saaty, the AHP is designed to cope with the intuitive, the rational and the irrational when one is involved with making multiobjective, multicriterion and multifactor decisions with or without certainty for any number of alternatives.

In the paper, "Axiomatic Foundations of the Analytic Hierarchy Process", Saaty [14] emphasizes that the approach to a decision problem must be
simultaneously simple and complex. Simple in the sense that it can be used easily and complex or robust enough to handle real world decisions. Saaty recognizes three stages in problem solving:

1. principles of decomposition.
2. comparative judgements.
3. synthesis of priorities.

By means of a simple introduction in both his book [13] and Management Science article, Saaty illustrates AHP with the goal or focus of selecting the best school. The criteria at level two include excellence, cost and location and level three comprises the alternatives, colleges A and B.

There are four basic steps in using the Analytic Hierarchy Process to solve a decision problem:

Step 1: Breaking down the decision problem into a hierarchy of interrelated decision elements.

Step 2: Collecting input data by pairwise comparisons of decision elements.

Step 3: The "eigenvalue" method is used to estimate the relative weights of decision elements.

Step 4: Aggregate the relative weights of decision elements to arrive at a set of ratings for the decision alternatives (or outcomes).

The Analytic Hierarchy Process is based on a set of four axioms which were first stated by Saaty [14] and are also described by Harker and Vargas [8].
Historically and theoretically, from its axioms through to its procedures, AHP is a very different and independent technique of decision making from utility theory. However, in the past decade AHP has tended to remain on the edge of mainstream decision analysis research due to this reluctance of practitioners to move away from traditional methods of analysis such as the Delphi technique and multi-attribute utility theory (known as MAUT).

Throughout much of its short history the Analytic Hierarchy process has been rather controversial. What emerges are two parties in the debate. Dyer [2] and [3] has offered some serious criticism of the Analytic Hierarchy Process and Saaty [15], Harker and Vargas [9] have attempted to reply to these criticisms. A debate in *Management Science*, March 1990 where both parties could explain their respective positions reveal, if anything, that the result has not been consensus.

Basically, there have been four areas in which the Analytic Hierarchy process has been criticised:

(i) Lack of axiomatic foundation (which is surprising, given the elaborate framework).

(ii) Ambiguity of the questions that the decision maker must answer.

(iii) The scale used to measure intensity of preference.

(iv) The principle of hierarchical composition and rank reversal.

Acceptance of the Analytic Hierarchy process has been slowed by mainly two factors:

(a) misunderstandings of its theoretical foundations.

(b) a reluctance to move away from traditional methods of analysis such as the Delphi technique and multiattribute theory.
However, one tends to come to the conclusion that Analytic Hierarchy process is a simple yet elegantly structured method for analysing decisions. In this light and in linking the field of Quality and Analytic Hierarchy Process there is certainly room for future development. Both encourage a teamwork approach.

Interestingly, Saaty states that if judgements are being conducted on a multi-evaluator basis, then the geometric mean should be applied to the judgements which derives from the requirement that the collective judgement itself must satisfy the reciprocal property.

Analytical Hierarchy Process as a means of measuring market segmentation is mentioned in an IBM case study in the TQMI Second National Conference Proceedings [17], so some initial steps have been taken linking customer satisfaction with AHP.

5. CONCLUSION

Most companies these days regard customer satisfaction as an essential part of a company's operations. There is certainly opportunity for future research to try to bridge the gap between how companies regard the customer as important and how they measure customer satisfaction.

Future research in Quality Function Deployment requires a quantitative approach to customer information processes. Two means of achieving this quantitative approach are to continue research into conjoint analysis and Analytic Hierarchy Process. They are rigorous techniques - not based on intuition or "what feels best".
Another direction is to continue research into incorporating engineering design and customer space. Although QFD seeks to integrate the customer information with the engineering variables a strong statistical measure should be in evidence in the engineering space. Design of experiments is appropriate to determine which engineering variables most affect customer attributes. In both the engineering space and customer space one has arrived at a House of Quality that is predominantly quantifiable that can potentially achieve a truly customer-driven product development. Otherwise, quality will not work at all if it means nothing else than a few enthusiastic speeches, lapel pins and embracing ideas well before the practical realities have been faced.
BIBLIOGRAPHY


APPENDIX : THE HOUSE OF QUALITY

Counterpart/Quality Characteristics

Customer Requirements and Rating of Importance

Relationship Matrix

Marketing Information and Customer Perception of Existing Competing Products

Technical Assessment and Target Values

Correlation Matrix
