Synthesis of market research data through a combined effort of QFD, value engineering, and value graph techniques

Biren Prasad

The author

Biren Prasad is Senior Corporate Consultant and Director of EDS/Delphi Automotive Systems, Automated Concurrent Engineering (ACE) Group, West Bloomfield, Michigan, USA.

Abstract

The focus of market research is to capture systematically product information, such as, market competitive analysis data, competitors' product data, etc. The paper describes an integrated template for product improvement by tactically combining real-time market research data with quality function deployment (QFD), value engineering, and a value graph. The focus of integrating market research data with QFD previously had been to develop analysis results – customer importance ratings (CIRs) and technical importance ratings (TIRs). The focus of integrating the QFD analysis (TIRs and CIRs vectors) with value engineering and value graphs, proposed in this paper, is to prioritize these ratings, to synthesize market research data, and thereby predict a better set of improvement characteristics. This process template gives the product development teams (PDTs) a synthesis tool to predict what product offerings customers would be interested in – which the company can build and market to make a fair profit.

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · pp. 156–172
© MCB University Press · ISSN 1352-2752

Introduction

Besides fear of declining profits, companies today are facing a variety of new challenges. Persistent among these are global competition, increasing labor costs, rising customer expectations, shorter product life cycles, and increased government regulations (Clark and Fujimoto, 1991). The older techniques of coping with "short-term fixes" in "reactionary modes" for product developments have not been enough to sustain increasing global competitive pressure (Dika and Begley, 1991). Today, more and more companies are focusing on "precautionary measures" (that is they are concentrating on problem prevention rather than fighting fires most of the time) while developing their products (Day, 1993). There is a need to plan ahead, combine the available corporate talents – marketing, management consultants, design engineers and manufacturing staff – to work closely together and somehow plan a product, which has all relevant life-cycle values. By designing and manufacturing products that reflect the customer's desires and tastes, everybody wins. Customers see the benefits and are willing to purchase the products. Manufacturers bag more profits. Today, many companies are interested in improving their competitive position in the world marketplace (Terninko, 1997). It is important for these companies to bring in to the market new product innovations and value-added services in a timely fashion (Wilson and Greaves, 1990). This is because those companies that introduce new concepts fast and at high quality levels often wrestle away with the largest share of the market. Timely product development benefits a company in many ways (Prasad, 1998):

- By early introduction, the company gains the customers' confidence, they see their needs filled and buy the products. The company gains easy market share, giving itself a competitive advantage.
- Customers get familiar with the products and, thus, they develop loyalty and are less likely to switch.
- The company gets on the learning curve ahead of their competitors.
- The company is able to set the product price and reap its profits much longer.

In order to develop a product that customers like, companies must know the wants (must-have), needs (like-to-have) and desires (wish-to-have) of their customers – the end users of

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

products or services – and of their business. Market research with quality function deployment (QFD) has been used many times before for computing customer importance ratings (CIRs) and technical importance ratings (TIRs) (Prasad, 1993). These ratings by themselves do not do much good unless they are tacitly applied with product improvement ideas. Many QFD combinations have been tried before with product development teams (PDTs) (Prasad, 1996), with voice of the customer (VOC) (Akao, 1990; Griffin and Hauser, 1991; Mizuno and Akao, 1994), and with total quality management (TQM) (Ungvari, 1991). In new product development areas (Liner, 1992), QFD combinations have been tried with Pugh's concept (Pugh, 1991) for product alternative selection (Clausing and Pugh, 1991) and for new product introduction (Liner, 1992). In conjunction with Taguchi methods, QFD has been combined with Taguchi formulation (Taguchi, 1987; Taguchi and Clausing, 1990), Taguchi with design of experiments (Ross, 1988), and Taguchi with TRIZ methods (Russian theory of inventive problem solving) (Terninko, 1997). In conjunction with optimization formulation, QFD has also been combined with multiattribute design optimization (Locascio and Thurston, 1993), with nonlinear programming techniques (Prasad, 1993), and for decisions using fuzzy sets (Masud and Dean, 1993). QFD has also been tried with concurrent engineering (CE) techniques (Prasad, 1996; Scheurell, 1992), for integrated product development (Prasad, 1997), with design structure matrix (DSM) (Harr *et al.*, 1993), and with design function deployment (Evbuomwan *et al.*, 1994) to obtain concurrent design. Though each QFD combined implementation in the above examples provided new opportunities and stronger contributions towards cost and productivity improvements, many of such programs have encountered difficulties in making a parent company globally competitive (Sivaloganathan and Evbuomwan, 1997). Furthermore, the gains that would seem obvious and feasible through an exploitation of QFD and its combination (in quantifiable competitive sense) have not always been fully realized (Prasad, 1997). The problem is that QFD combinations by themselves do not offer predictive solutions for product improvements unless they are also integrated with both an analysis and a predictive tool. The paper has extended this idea by integrating TIRs and CIRs with value engineering and value graphs to obtain priorities (relative preferences) for product improvement characteristics. The use of QFD with value engineering gives the customers not only what they consider important for themselves but the priorities of building such quality characteristics into the product based on a number of considerations, which are essential to the company, the customers, and the organization (extended supply-chain continuum) as a whole.

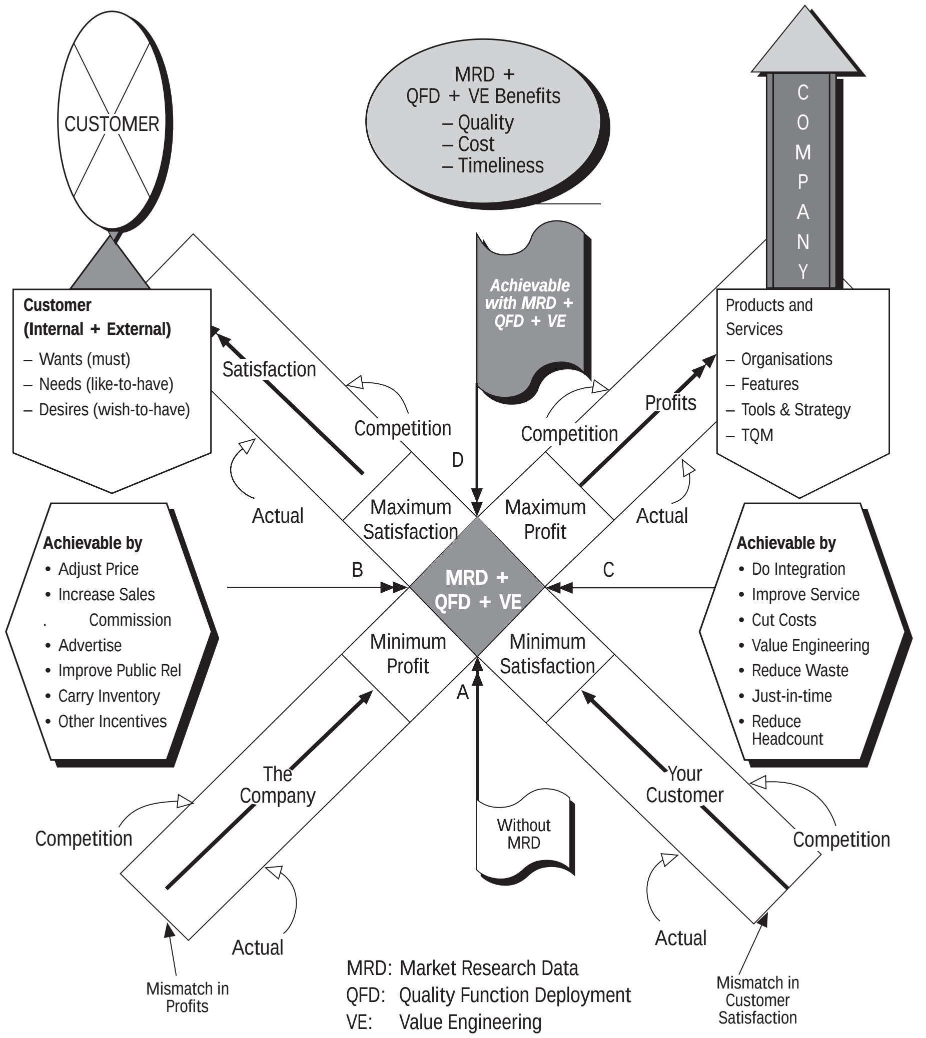
This is schematically shown in Figure 1. Two objectives are shown crossing each other at a 45-degree angle:
(1) Company profits.
(2) Customer and/or employee satisfaction.

Two parallel lines are shown separating a company's current level from its competition's level. They cross in the middle creating four cross-points (A, B, C, and D). Each cross-point on the chart (Figure 1) reflects a state of a company depending upon its choice of strategies:

- *Level A*. This is the bottom-most cross point. This level reflects the most poorly performing company. At this level, there exists minimum customer and employee satisfaction and a marginal profit. This is often the case when companies are desperately trying to win back the lost customers and are not performing well (showing a poor return on investments). When a product does not measure up to the customer's expectations, it does not sell well. This often forces companies to introduce incentives to move their product lines faster. Some of these techniques are quite expensive, since they cut into the profit margins. Companies that engage in those tactics reach a level B or level C on the chart.
- *Level B*. Some companies reach level B by adjusting price, increasing sales commission, advertising heavily, improving public relations, carrying extra inventory or by other similar incentives. Resorting to such fixes does improve customer satisfaction temporarily. However, it comes at the expense of the company's gross profits. There are other kinds of fixes which can also help a company move away from level A.
- *Level C*. At this juncture, any increase in profit margin happens temporarily and that too at the expense of customer satisfaction.

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

Figure 1 Why combine market research data with QFD?



Level C shows this on Figure 1. Examples of such fixes are performing integration, improving service, cutting costs, value engineering, reducing waste, applying just in time, reducing head-count, or other similar means. In either situation (level B or C), the company is not able to achieve both – that is increase in customer/employee satisfaction and increase in profit margin.

- *Level D*. At level D, both the mismatches in customer/employee satisfaction and profits are removed. Market research with QFD is a technique that lets you achieve both these goals.

The major goals for performing market research, analyzing the data (compute ratings) with QFD, synthesizing results with value engineering and plotting them using value graphs are to incorporate customer voice during early design stages (Clausing, 1994), improve quality, functionality (X-ability), innovations (tools and technology), responsiveness and upgrade enterprise infrastructure.

Focusing on the types of customer

To understand what it takes to satisfy customers, one must focus on the "voice of the customers", which is represented only in part by the present customers. Customers who do not buy a company's product also have a voice. The definition of quality, as stated earlier, relates to internal as well as external customers. Everyone wants the information – the voice of the customers – to be timely, accurate, and straightforward. Information is extracted (solicited) or comes from (unsolicited) through a variety of means: information can come in an active sense (solicited) because the company is looking for it, or because it is told to do so (unsolicited). It can be measurable (quantitative), or it can be subjective (qualitative). It can be organized/arranged in

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

some order (structured) or it can be listed in a haphazard (random) way. No matter who is supplying the information, products or service, the recipients rely upon the information source (internal or external) for quality work. The internal requirements are as real as those of external customers – whether it is speed, accuracy or measurement. Defining quality as "managing conformance to specification in order to achieve customer satisfaction" represents a minimum set of "do's" that a company has to have (Deming, 1986). There are partners and internal customers who want their opinion to be sought, heard, and their issues to be addressed. The "voice of the customer" includes inputs from sources such as manufacturing, purchasing, field service, suppliers, etc. They represent a company's internal customers. Figure 2 lists four sources of market research data to develop customer requirements.

The major sources of market research data are:

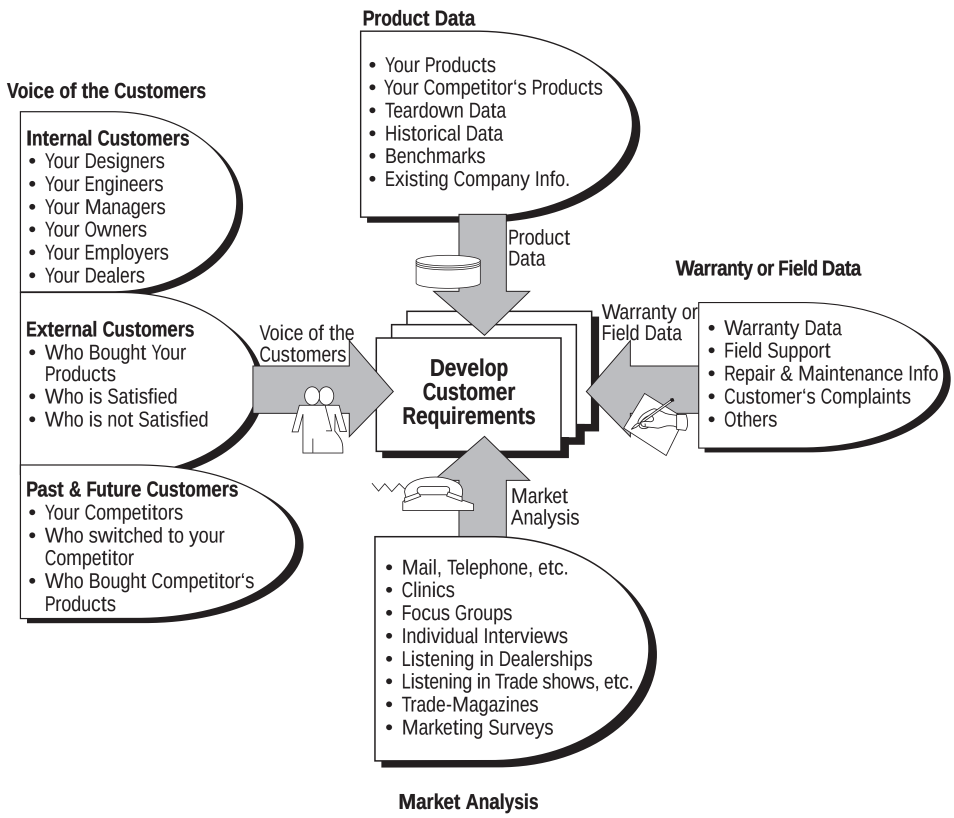
- voice of the customers;
- product data;
- warranty or field data; and
- competitive analysis data.

The voice of the customers' data – D_{voc} – is in turn a function of a number of three variables: internal customers, external customers, and past and future customers. Today, the customer focus is much broader than just satisfying internal and external customers. Additionally, it includes making products that delight the users and cause a positive attitude towards their value, usage and quality. As products become obsolete quickly in a highly dynamic marketplace, to many companies maintaining values over the life of a product is becoming one of the most important quality dimensions.

Focusing on combining market research data with QFD

The intent of using the two together (market research data with QFD) is to incorporate "voice of the customers" into all phases of the product development cycle, through concept, engineering and analysis, design, prototyping, production engineering and planning, management and control, manufacturing, and finally into delivery and support. In other words, market research with QFD provides a customer-driven product development methodology.

Figure 2 Sources of data to develop customer requirements



Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

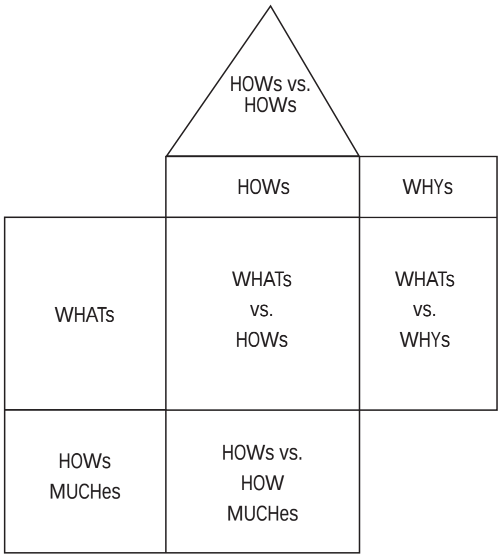
Quality function deployment (QFD)

QFD is a market-driven methodology for products and services to meet or exceed customers' needs and expectations (see Appendix for summary of methodologies used in this paper). Recent success can be attributed to industry interests in study missions to Japan and training in QFD offered by organizations like the American Supplier Institute (ASQC/ASI, 1992) and GOAL/QPC (Growth Opportunity Alliance of Lawrence, Massachusetts/Quality Productivity Center) (Akao, 1990; King, 1989). The first recorded case studies in QFD were in 1986 (King, 1989). Kelsey Hayes used it to develop a coolant sensor which fulfilled critical customer requirements like "easy-to-add coolant, easy-to-identify unit" and "provide cap removal instructions". A number of companies now use it, including Ford, General Motors, Chrysler, AT&T, Proctor and Gamble, Hewlett-Packard, Digital Equipment, ITT and Baxter Healthcare. However, it has not yet found popularity as a market research technique, though its use is appropriate for organizations of any size. Many companies are already experimenting with QFD ideas and applying them in diverse cross-functional team environments for problem solving (Bossert, 1991). These companies have realized large benefits. QFD focuses and coordinates skills within an organization, first to design, and then to manufacture goods that customers want to buy.

House of quality (HOQ)

The basic tool of QFD is the "relational matrix" concept. Matrices are schemata to define generically and relate directionally to multiple lists of identifiers, often referred as vectors (Prasad, 1993). The basic matrix of QFD is the "house of quality", so named since the triangular matrix which forms its top structure – the roof – makes the diagram resemble a house. The quality matrix in QFD translates the voice of the customer into the engineering, design, process and production stages. The original (ASQC/ASI version only had four rooms. Recent works have included "WHYs" in the matrix (see Figure 3). This way the definitions and manipulations of generic matrices can be combined into an "expanded house of quality". Expanded QFD enables support for all prevailing QFD approaches that have recently emerged. Figure 3 is a schematic view of an "expanded house of quality" (HOQ) (Prasad, 1993). This expanded house of quality has eight rooms. Four of the rooms form the basic perimeters of the house. These are lists of two row-rooms: "WHATs" and "HOW MUCHes," two column-rooms: "HOW" and "WHYs". Expanded HOQ also encompasses relationships between these lists resulting into four "relational matrices": "HOWs vs. HOWs"; "WHATs vs. HOWs"; "HOWs vs. HOW MUCHes" and "WHATs vs. WHYs".

Figure 3 Expanded house of quality (HOQ)

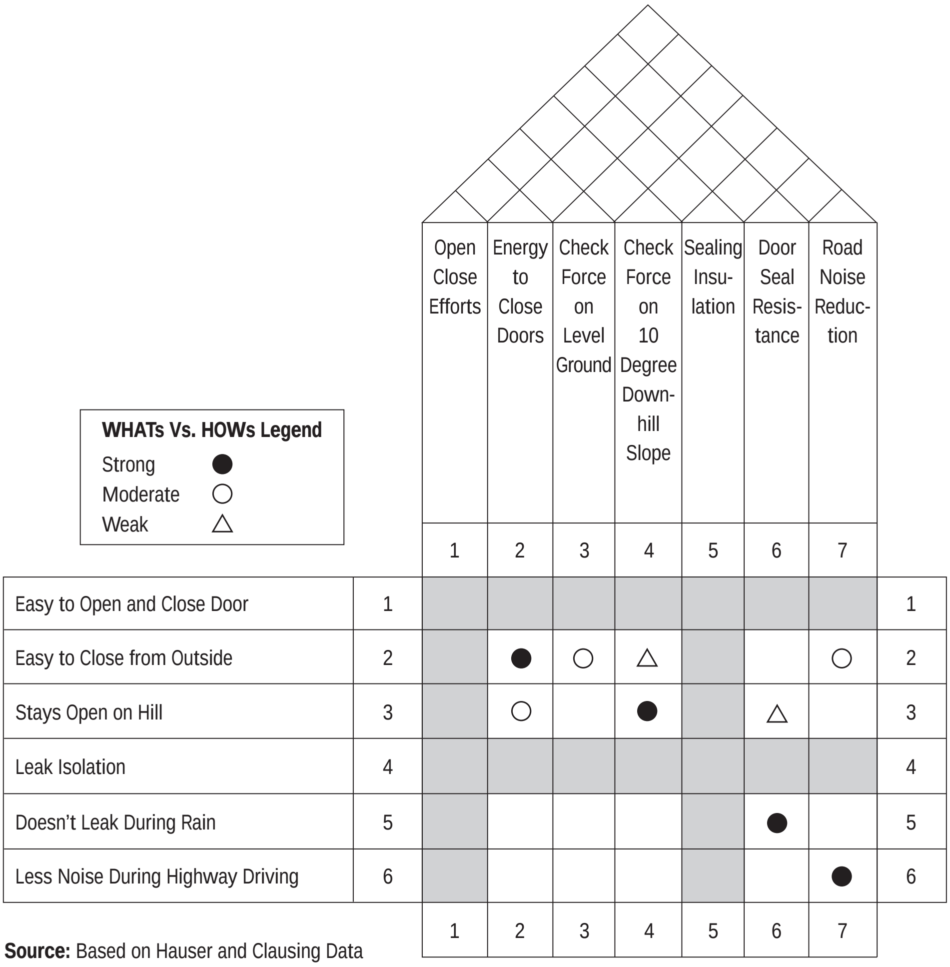


With market research as a front end to QFD, QFD becomes a "market-in" approach instead of a traditional "product-out" approach for integrated product development. The voice of the customer is collected, analyzed, and translated into like attributes, such as HOWs (technical characteristics), functions, reliability, WHATs (objectives and goals), and product breakdown structure (PBS) such as systems, sub-systems, components, parts, etc.

Figure 4 shows that, in simple terms, QFD relates a list of what the customer wants (for example, in the case of a car door, "easy to open and close", "isolation", etc.) to a list of attainable design requirements (for example, "opening and closing effort", "sealing insulation", etc.) (Hauser and Clausing, 1988). A list of "what the customer wants" comes from market research. There are many sources of data for performing market research. This is shown in Figure 2. For example, to get the "voice of the customer" data the marketing people have to ask the right questions of the consumers. To respond to the question "how do I satisfy my customer?", the marketing

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

Figure 4 Use of quality function deployment: a door example



Source: Based on Hauser and Clausing Data

people have to speak to the designer for the right answers. There is no point in the marketing people identifying something that is not feasible, or designers identifying solutions that do not add value for the customer. Such issues should therefore be resolved early in the product definition process.

The central matrix is used to identify the strengths of relationships between the "WHATs" and the "HOWs". For example, "door seal resistance" means that "rain does not leak in", but it will make it difficult to satisfy the "easier to close the door" criteria. The power of QFD is that it provides a logical way of focusing the analytical efforts of people (having different skills) and aligning them with selected actions (or indeed services – in Japan, banks use this technique). The simple matrix can be extended in several directions enabling customer-based assessments of current and competitive products. Critical parameters identified can be optimized in the design phase with Taguchi methods. QFD helps to deploy customer wants and needs to the appropriate design and delivery functions within one's organization.

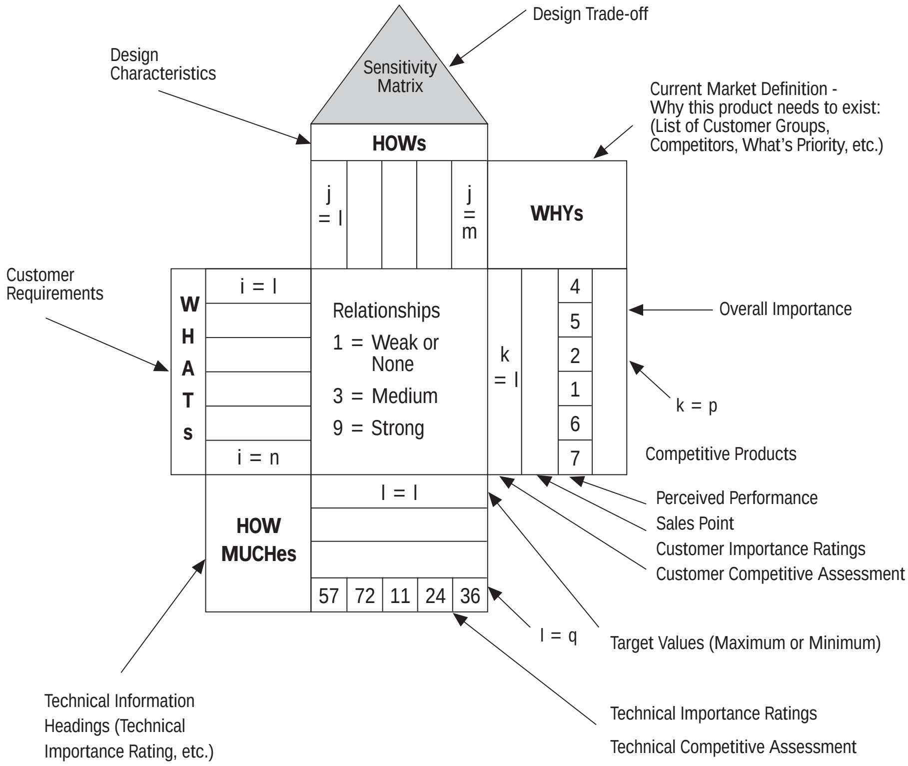
Though QFD has been used in many situations, the most common usage of QFD is for product improvement. A burning example of this is the actual design engineering changes to be brought about in the next version of the product that will incorporate a list of proposed customer desires for improvements. Usage of QFD for qualitative analysis of market research data has been very limited (Bascaran, 1991). Shillito (1994) has shown, however, that if the "technology to market" and company needs are coupled with QFD, its usage can be extended to market analysis.

HOWs: quality characteristics items

Manufacturers define what constitute HOWs in a QFD/HOQ. This is represented by a list-vector in the quality house marked as HOWs (see Figure 5). In simple terms, HOWs are a set of quality characteristics through which a set of WHATs can be realized. HOWs thus represent an array of design variables or solutions, which may or may not be independent.

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

Figure 5 Expanded house of quality – terminology and conventions



Each of the HOWs provides a set of solutions for attacking one or more WHATs (or CRs). Manufacturers do not know what magnitude of each of these HOWs when considered as a unit will lead to realization of as many WHATs as possible. HOWs provide an operational definition for the market quality characteristics. Using this list, a company can measure and control quality in order to ensure WHATs' satisfaction. The HOWs are the methods or techniques to translate the "voice of the customer" into design evaluation criteria. Typical entries on the HOWs vector-list are parameters for which means of measurements or a measurable target value can be established. For example, a customer need for a "good ride" (a WHAT) is achieved through "dampening", "shock isolation", "anti-roll", or "stability requirements" (the four HOWs). The HOWs determine the set of alternate quality features to satisfy the stated customers' needs and expectations (WHATs). For this reason, HOWs are also called quality characteristics (QCs). A typical HOW might be a "length", a "width", a "height", a "thickness", a "usable surface area", a "volume", a set of "material characteristics" or "mass properties", etc.

For every WHAT in the RCs list, there are usually at least one or more HOWs to describe possible means of achieving customer satisfaction.

HOW-MUCHes: bounds on quality characteristics

This is a vector-list and normally identifies the bounds on the feasibility of HOWs. These entries are in the vector-list called HOW-MUCHes and represent the target values for each quality characteristic (see Figure 5). In other words, for each HOW on the list-vector, there is a corresponding value for a HOW-MUCH entry. The idea is to quantify the solution parameters into achievable ranges or specification table, thereby creating a criterion for assessing success. This information is often obtained through market evaluation and research. HOW-MUCHes capture the extremes – the permissible target values, positive or negative – depending upon the HOWs sentence construction or statements. A typical HOW-MUCH measures "the importance of HOWs", a "performance of Product X", or a set of "target values". Most commonly, a PDT team, through a row of feasibility matrix, establishes a set of realistic target values (upper and lower bounds) for each HOW. Product values or target values identify engineering tolerances and specification limits on QCs. For a value-based

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

synthesis formulation discussed in the fifth section, a row of HOW-MUCHes is used to collect upper and lower bounds for the attributes in the HOWs vector-list.

WHYs: weighting factors on WHATs
Similar to WHATs and HOWs, a set of WHYs are also a vector-list which describes the relative importance of current competitive products referred to as "world class" or "best of the class" products. The best of the class contains HOWs that satisfy a set of WHATs in some prioritized manner (see Figure 5). This is the chosen way in QFD of defining a relative priority for the WHATs objectives. If a product solution (a HOW) exists today, a vector of such HOWs can be looked upon as proportions in which customer requirements (WHATs) are satisfied. A HOW is the way to assess feasibility of the product in the marketplace. A HOW list helps to define the target projection in relation to the WHATs list. Once these target values are multiplied with the corresponding set of WHATs and then summed over, they can provide a single pseudo measurement index for the "overall customer satisfaction". In terms of optimization this can represent a weighted sum of objectives. An example of WHYs is a vector-list of relative importance with respect to customer wants for a "world class product" of a competitor with whom someone would like to compete. If the product is targeted to multiple customer groups, such as American, Asian, European, Japanese, etc., this list must include these customer groups and their relative wants. WHYs are names of competitors, competitive products, market segments, or other items which describe the current market conditions. WHYs are also factors for "weighing" decisions which a future product must take into account. This usually translates into specifying "weighting factors" for WHATs. Setting priority means specifying what is significant in the list of WHATs and what is not. A typical WHY might be a vector-list of "overall importance", a vector list of "importance to the world purchaser", or a set of "world-class achievable performance of a product X".

HOQ relational matrices

The four relational matrices are described in this section. HOQ relational matrices employ either numbers or symbols depending upon the purpose of QFD and the context in which QFD is being used (see Figure 5). Two possible rationales have been traditionally proposed depending on whether a relational matrix is used for calculations or for visual aid.

(1) *Quantitative reasoning*. Numbers are used for specifying magnitudes of HOQ matrices. This facilitates comparing magnitudes of computed vector-lists through mathematical means.
(2) *Qualitative reasoning*. Symbols are used to represent list-vectors or matrices. This provides a better visual communication. Three symbols are often used to indicate the relationship between the entries of WHATs and the HOWs. A solid circle (●) implies a strong relationship, an open circle (O) a medium relationship and a triangle (Δ) a weak or small relationship.

This process of evaluating expressions in QFD gives a concurrent team member a basic method of comparing the strengths and weaknesses, importance of column-vectors (WHATs, WHYs) or row-vectors (HOWs, HOW-MUCHes) and measuring interactions between them. The notations used here follow the convention adopted by the employees at the Kobe shipyards who incorporated the local horse racing symbols. By convention, each symbol in the relationship matrix receives a value. Table I shows a convention that is typically followed in defining QFD relational matrices.

WHATs versus HOWs: correlation matrix relationship between market requirements and quality characteristics (QCs)
To get a relationship between market requirements and quality characteristics, a matrix is created by placing the HOWs list along the column of a matrix and the WHATs list along its rows (see Figure 5). The rectangular area between the rows and the columns then depicts the relationships between the set of WHATs and the HOWs. The matrix thus developed is called a relationship matrix. It correlates what customers want in a product and how an enterprise can achieve those objectives. The matrix – "WHATs versus HOWs" – is a core relational matrix of QFD. Relationships within this matrix are usually defined using a four level procedure: strong, medium, weak or none (see Table I). An example is shown in Figure 5. This matrix may be densely populated (more than one row or column affected). This results from the fact

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

Table I Standard relationship conventions (weight and symbols)

Matrix	Grade	Quantitative weight	Qualitative symbols
WHATs versus HOWs	Strong relationship	9	Double or solid circle and/or ●
	Moderate relationship	3	Circle (O)
	Weak relationship	1	Triangle (Δ)
	None	0	Blank
HOWs versus HOWs	Strong positive relationship	9	Double or solid circle and/or ●
	Medium positive relationship	3	Solid triangle (Δ)
	Positive relationship	1	+
	None	0	Blank
	Negative relationship	–1	–
	Medium negative relationship	–3	Open triangle (Δ)
	Strong negative relationship	–9	Open circle (O)

that some of the quality solutions may affect more than one market requirement. For example, what a customer wants in "good ride" and "good handling" (WHATs) are both affected by quality characteristics like dampening, anti-roll or stability requirements (HOWs). The more densely populated and spread in ranks the correlation matrix is, the more valuable the information (relationship) is likely to be. A diagonal correlation matrix means there is none or very little interaction between the rows and the columns. HOWs could also include some design evaluation criteria: such as, how do we know we can satisfy our customers, how can we test, how can we control the quality, etc.

Types of results obtained through analysis of market research data with QFD

The four key relational matrices in the house of quality discussed earlier are useful in drawing conclusions about the relative importance of WHATs, WHYs, HOWs and so on. There are some computer programs and softwares (QFD/Capture; Hales *et al.*, 1990) that allow you to enter these matrices interactively. They also provide a variety of sorting and matrix analysis algorithms such as weighted average, ranking, technical importance, normalized ratings, sum of WHYs or HOWs matrix column, weighting factors, graphics utilities (bar charts, line chart), etc. In the next section, some results obtained through analysis of market research data with QFD are described.

Competitor product assessment

Competitor product assessment charts are used to assess two things: rate the requirement of a competitive product and rate the quality characteristics for the same competitor's product. There are two types of competitive assessment.

(1) *Customer competitive assessment* (CCA) is developed from customer surveys. Customers are asked to rate the requirements of a competitor product. They are asked to identify what they liked in a competitor product and what they did not like including their preferences of one requirement with respect to the other. In the house of value, this is entered in a column of a "WHATs versus WHYs" relationship matrix. Customer competitive assessments rate the WHATs (perceived response).

(2) *Technical competitive assessment* (TCA) is also developed from customer surveys. In a similar fashion, the quality characteristics (HOWs) for the same competitor product are rated here from a technical perspective. The customers are asked to rate the features they find interesting in a competitive product including the ones they did not like. TCA represents the customer's opinion of quality characteristics (that is interesting features) found in a competitor product in a particular marketplace. In the house of quality, this is found in "HOWs versus HOW-MUCHes" relationship matrix. Engineering assessments quantify the HOWs (engineered or measured outputs).

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

When the two assessment values (CCA and TCA) are in conflict, it is often a result of failing to understand the "voice of the customer". In such a case, the HOWs list must be amended to reflect customer perception. This is most often resolved by letting PDT members directly get involved in the process of comparing the in-house and the competitive products.

Company product assessment

Competitor product and company product assessment charts are used in HOQ to compare the requirements and the quality characteristics of a competitor product with a company product. The following are two types of ratings commonly used in QFD to rate the importance of requirements and importance of QCs of a company product:

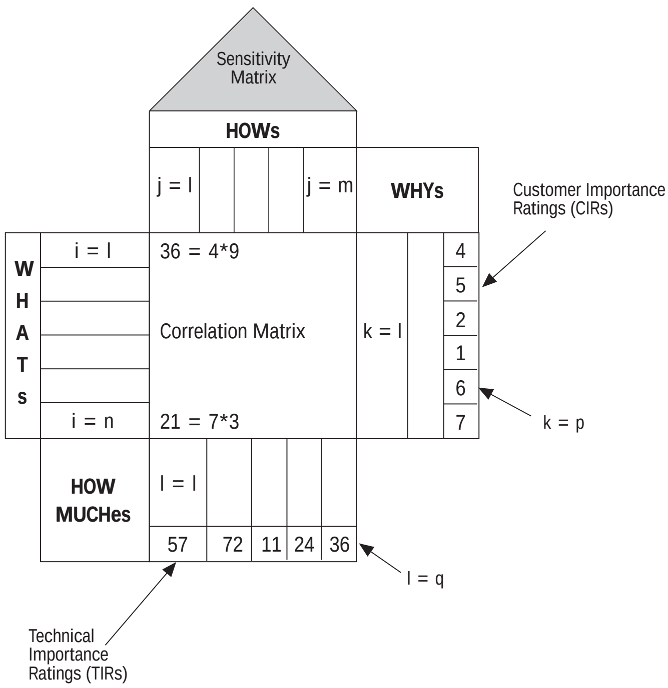
(1) *Customer importance rating* (CIR) is derived from the field or customer surveys. The customers (users of the company products) are asked to rate the requirements which customers perceive to be important for the manufacturer to consider in a product. They are also asked to identify what they would consider important in a future product and what they would not. These ratings are for each WHAT based on overall evaluation of the products in the field. It is posted as a column of the "WHATs versus WHYs" matrix.

(2) *Technical importance ratings* (TIR) are the results of calculations from the QFD matrix defined earlier. It is not a direct results of customer surveys as in TCA. The customers are only required to rate the requirements (WHATs) and prioritize the importance of each with respect to the rest. This is done in the above step called CIR. The information is used later in the calculation of TIR. The steps used in the calculation of TIR are as follows:
   - Assign a numerical value for each symbol used in the correlation matrix "WHATs versus HOWs". Conversion listed in Table I is most commonly employed.
   - Corresponding to each WHAT multiply the "WHATs versus HOWs" equivalent numerical value of the correlation matrix by the "WHATs versus WHYs" CIR value.
   - Repeat the results of multiplication in the previous step for all WHATs and add the results in each HOW column.
   - Enter the results of the final step into a "HOWs versus HOW-MUCHes" row. The row of computed numbers stored in "HOWs versus HOW-MUCHes" matrix represents a TIR for each HOW. If that row is a lth row of HH matrix.

Ratings, stored in a lth row of "HOWs versus HOWs MUCHes" matrix, are a relative comparison of each jth element, provided the kth row contains the CIRs as shown in Figure 5.

Figure 6 illustrates the sequence of steps involved in computing the technical importance rating (TIR). A "WHATs versus WHYs" column in Figure 6 contains an example of the customer importance rating (CIRs) values obtained through surveys. A typical correlation matrix may have symbolic representation. If so, they are first converted into a quantitative value matrix using the conversions shown in Table I. As shown ,9 is equivalent of strong and 3 is an equivalent quantitative value for weak symbol. These quantitative values in a cell (i,j) are multiplied by the ith customer importance ratings (CIRs) (4 and 7 stored in the kth column of "WHATs versus WHYs" matrix), resulting in

Figure 6 QFD application to determine ratings



Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

an importance value for each (i,j) location in the matrix. The technical importance rating for each HOW (jth location) is then found by adding together the importance values in each jth column. As an example, in the first column of the matrix in Figure 6, the first relationship has a value of 36 (= 4 × 9), and the only other relationship has a value of 21 (= 7 × 3). The technical importance rating for this column (a HOW) is thus the sum of these two values, 57 (= 36 + 21). Technical importance ratings are used to determine which of the HOWs should receive the most resources and are particularly useful in trade-off decisions. The numbers 4 and 7 chosen in Figure 6 have no significance except to show the computational steps involved. Technical importance rating is finally stored as an element of the "HOWs versus HOW-MUCHes" matrix. Other elements might include service repair/cost data, technical difficulty, safety control items, newness, reliability, timings, cost, etc. (see Figure 5). It is impossible to fill-in CIRs and complete TIRs effectively without multidisciplinary teams. Additional tables can do the same with suppliers and end-users of the product.

A significant outcome of a successful QFD application is establishing a process of smooth communication between the work-groups, which allows the communications to take place.

An integrated template for product improvement

In the following a product improvement template is proposed which is based on integrating market research data with QFD and gluing it with value engineering. In this context, first, a product development team starts with a market research proposal, then a QFD analysis is done. This results in the initial computations of technical importance ratings (TIRs) and customer importance ratings (CIRs). The initial QFD rating analysis is followed by a synthesis of the two based on value engineering. The trio combination < market research + QFD rating analysis + value engineering-based synthesis > often leads to a more balanced result. The following are the major steps of this integrated template.

Plan for "as-is" activity charting

Activity charting is an important step of value engineering for building quality into the product realization process. This involves the following:

- identifying who and what has been done so far;
- reviewing and prioritizing the work to be done;
- putting together a policy document outlining purpose, scope and deliverables; and
- reviewing with the management and getting their approval.

The plan for "as-is" charting focuses on the entire manufacturing process and their interfaces, rather than its subset. The normal procedure is to start with one key area and use this as a team exercise.

Identify functions of the product or services

The next major task is to review the "current" process for this area and to get all the relevant facts. For example, the team gets: information about specialty products, materials, processes, vendors; and talks to company and industry experts to understand the functions they are performing.

(1) *Begin workflow modeling*. This step includes drawing a process flow-chart (following the standards for flow-charting) in minute detail identifying "what is planned to be done". Besides documentation, time-based examination of workflow is detailed. A structured format is used to emphasize the impact of sources of variations on the process. The emphasis is on "procedure" source not its agent, or the person who is running the procedure. In addition, the tasks involved in this step are:
   - *Define a candidate process model or value tree*: the result of this charting is the development of specifics – important data and objects – called "candidate" process model.
   - *Draw value graph – process description sheets*: the team should be able to break down the flow into smaller chunks in a form of a process description sheet so that each chunk accurately describes the associated manufacturing method.
   - *Identify sequence*: it identifies sequence, the main assignments, part flow, timings, etc.
   - *Identify indirect expense and control parameters* (such as statistical quality

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

control (SQC), statistical process control (SPC), and schemes associated with Just-in-Time manufacturing).
- *Identify process parameters*: during this step, process assumptions are identified, machines and people are sketched, and critical process characteristics are confirmed.
- *Identify new investment*: new machinery or equipment cost is also identified and estimated, and noted against the appropriate entry in the bill-of-material.

(2) *Develop performance metrics*. These are criteria by which organizations measure efficiency and improvement. This is equivalent to a set of WHATs in the QFD matrix described in the second section. Building on WHATs in QFD, managers can perform activity-based analysis for measuring process performance while identifying critical performance drivers. Better performance metrics are critical to product improvement success. WHATs in QFD give managers clues to measure the value of the system.

(3) *Establish a value for each quality characteristic (QC) function or service listed as an element of a HOWs row*. The process begins with looking at the "candidate" process model of an enterprise. One then performs functional economical analysis in support of process redesign and new investment justification, if any. The teams model the process using icons and blocks in addition they do the following:
- *List sources of variations*: the team lists all sources of variation potentially affecting each operation.
- *Identify value-added activities*: brainstorming and team dynamics are tools often used to identify value-added activities from non-value added activities in the "candidate" process. We may never be sure, but we can break down the activities in the following three categories that are helpful in making this assessment (Roberts, 1994):
  – *Real value added (RVA)* – refers to the activities that are essential to the process in order to meet the essential customer expectations.
  – *Business value added (BVA)* – refers to activities essential to conducting business, such as employee happiness, benefits (vacation, sick leave, etc.), policy and regulation compliance, that add cost or time to the process but do not add value from the customers' perspective.
  – *No value added (NVA)* – refers to activities that neither add value to the process from the customers' perspective nor are required to conduct the essential business. Examples of NVA include unnecessary indirect costs (such as storage, movement, multiple measurements, end-of-the line monitoring, tracking, all forms of duplication, rework, long approval cycle, etc.) Departments collect these types of costs under the heading of "overhead" or "burden". Some indirect costs are not so "bad" others do not add much value to the corporation. Most re-engineering teams are not trained or motivated to make indirect costs as part of their "process re-engineering" equation, despite the fact that this is perhaps the best place to begin attacking them.

Synthesize QCs using value engineering

Value engineering is used here as a basis to synthesize or rank critical QC items (solutions or functions) listed in the HOWs row of a QFD matrix. The value engineering begins with the "as-is" process flow-charts. One looks for each QC item for improvements and process areas on the as-is flowchart, where some perturbations can be possibly made. However, it is usually not clear, looking at the flow-charts, which of these solutions/ functions ought to be changed, modified or expunged and why. One does not readily know what basis to use in setting up the change priorities. What is lacking is a rational basis for decision-making – which QC solution is important and which is not. Though, value engineering provides one such basis, many other criteria do exist. Some criteria used in this context are (Prasad and Strand, 1993):

- *Critical index*. This is a measure of criticality. This index is assigned a value of 1 if a QC solution falls on the critical path and 0 if not. Thus critical index takes a logical value of 0 or 1.

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

- *Time-index*. This is a measure of how long it takes to perform a QC function.
- *Cost-index*. Some QC solutions cannot be measured by time but require capital investment. Cost-index is a measure of the cost associated with performing a QC solution.
- *Issues-index*. Often, some QC solutions are subject to a lot of management and implementation issues not related to either time or cost. Issues-index provides such measures.
- *Priority-index*. As defined earlier, it measures the priority of performing one QC solution/function in relation to others.

It has been difficult to decide which one of the above indexes should be used as a basis of determining the importance of a QC solution or a function. If one index is considered more important than others, it might be true for one set of QCs but may not for the others. We needed a schema for arriving at a total value index from the individual indexes. This section describes such a schema. Table II shows a partial result of combining the individual indexes. The principles on which the total value index is obtained are derived on the basis that each index is equally important from process improvement considerations. If this is not true, weighting factors can be assigned to the indexes to balance the results out. The following describes the approach.

Let us assume S_{ij} is a measure of jth index for an ith QC item. Then the total value index ratings can be formed as follows:

$$\text{Normalized index } N_{ij} = S_{ij} / L_j; \quad (1)$$

$$\text{Where, } L_j = \sqrt{\sum_{j=1}^{j=5} \{ [S_{ij}**2] \}} \quad (2)$$

If w_j is the weighting factors associated with the indexes,

$$\text{Where, } 0 < w_j < 1.0 \quad \text{for } j = 1, 5 \quad (3)$$

$$\text{and} \quad \sum_{j=1}^{j=5} w_j = 1.0 \quad (4)$$

The total value index can be obtained as:

$$\text{Total value index, } R_i = \sum_{j=1}^{j=5} \{ [N_{ij}] * w_j \} \quad (5)$$

The normalized total value index (ranking of R_i)can be obtained by:

$$\text{Normalized cumulative effectiveness factor (CEFs)} = R_i * 100. / \sqrt{\Sigma \{ [R_i**2] \}} \quad (6)$$

It may be noted that j = 1 indicates the critical index, j = 2, 3, 4 and 5 denote time, cost, issues and value indexes, respectively.

The method outlines how to obtain an effective combined index rating from a set of individual indexes. The activities which are closer to 1.0 mean that those are quite important. The activities which are closer to 0 and less than 0.5 represent weak links. They represent candidates for possible modifications or elimination.

Plot synthesized results on value graphs

Equation (6) gives a normalized cumulative effectiveness factor based on value-based criteria. One can combine this approach with normalized relative importance rating obtained from QFD analysis in the fourth section . Using these two ratings, one can also compute a value index as follows:

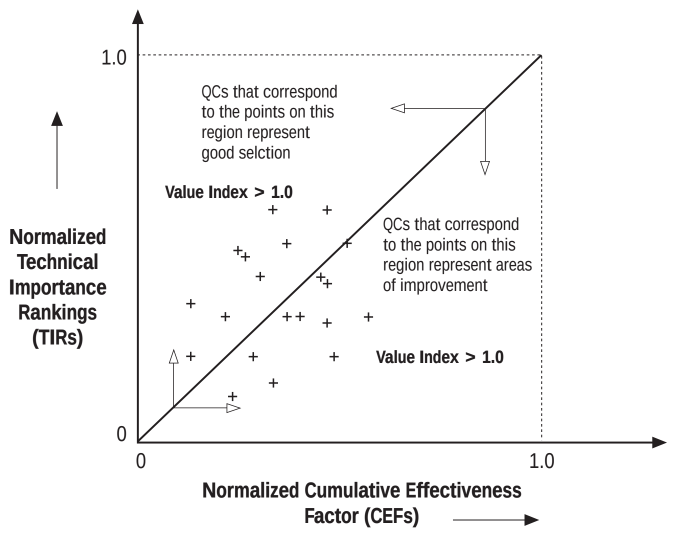
$$\text{Value index} = \frac{\text{Normalized technical importance (TIR) rating obtained from QFD}}{\text{Normalized cumulative effectiveness factor (CEFs) by equation (6)}} = \frac{TIR_i}{CEF_i} \quad (7)$$

Value index is defined here as the ratio of the normalized technical importance rating (TIRs) computed using QFD and the normalized cumulative effectiveness factor (CEFs) computed from equation (6). Since each QC has a corresponding TIR value, there will be as many value-indexes as TIRs. These indexes can be plotted on a value graph (see Figure 7). The points on the value graph represent the value index for each of the QCs. The value points, which fall on the diagonal line (slope = 1) represent a break-even point. The points which fall bellow the unit slope line represent the areas of possible improvements in performance or efficiency. The points which fall above the unit slope line represent the good points. The major goals of integrating market research with QFD, and synthesizing the results using value engineering are to incorporate customers' voice and market preferences early on during product launch and thus reduce future product change orders and engineering changes. Synthesizing

Table II Relative ranking of the activities

Die-processing data synthesis matrix		Individual basis of ratings and specifications					Die-processing data synthesis matrix – Overall rating			
Activity no.		Does it fall on the critical path (yes = 1; no = 0)	How long it takes to perform the activities (hours)?	What are equivalent direct indirect costs (in K$)?	Influence of the activity on the issues identified	Does this activity add value to the work (yes = 1; no = 0; Don't know = 0.5)?	Relative severity index calculations			
Type	Activity description	Critical Index	Time Index	Cost Index	Issues Index	Priority Index	Weighted Value	Weighted Rank	Average Value	Average Rank
Weighting factor		20%	30%	20%	20%	10%	1.00		1.00	
Minimum value		0	0	1	0	0	0.03		0.03	
Maximum value		1	4	1	1	1	0.29		0.28	
Normalized value		4.58	8.74	5.74	1.60	3.91	0.78		0.77	
Standard deviation		0.49	1.23	0.00	0.27	0.47	0.07		0.06	
S1	Advanced prints (if any)	0	0	1	0	1	0.06	1	0.09	2
S2	Plant information (press information)	0	0	1	0	1	0.06	1	0.09	2
S3	Receive work order from SME for die processing	1	1	1	1	0	0.24	8	0.23	8
S4	Input work order and assign job to die processor	1	1	1	0	1	0.14	4	0.15	5
S6	Start of die processing or die pre-processing phase	0	0	1	0	0	0.03	0	0.03	0
S7	Review work order and advanced prints if available	0	4	1	0	0.5	0.18	6	0.15	5
S8	Upload latest product data from CAD System	1	1	1	0	1	0.14	4	0.15	5
S9	Is this a new part?	1	0	1	0	0	0.08	2	0.08	2
S10	Product released databank (corporate)	0	0	1	0	0	0.03	0	0.03	0
S11	Is the released data same as preprocessed?	1	0.5	1	0	0	0.10	2	0.09	2
S12	Are there any major changes since last process?	1	0.25	1	1/3	0	0.13	4	0.13	4
S13	"Input from formability platform, senior manufacturing engineer "	0	0.5	1	0	1	0.08	2	0.10	3
S14	Tip part (based on user experience)	1	2	1	0	1	0.17	5	0.18	6
S16	Determine die type and number of die operations	1	4	1	0	1	0.24	8	0.22	8
S17	Versatec tipped plots (full-size or scaled down)	0	0.25	1	0	0	0.04	0	0.04	0
S18	Is any product change required?	1	0.25	1	0	0.5	0.10	3	0.11	3
S19	Change request signed off by senior manufacturing engineer	0	0.25	1	0	0	0.04	0	0.04	0
S20	DES user files (mainframe)	0	0	1	0	1	0.06	1	0.09	2
S21	Is this acceptable by SME and design staff?	1	0.5	1	1	0	0.22	7	0.22	7
S22	Write die line-up (minus blank die) information	1	3	1	2/3	1	0.29	10	0.28	10
S23	Preliminary die line-up review	1	1	1	0	0.5	0.13	4	0.13	4
S24	Preliminary line-up given to layout and design group	1	0	1	0	1	0.10	3	0.13	4
S26	Update line-up as required	1	2	1	0	0	0.15	4	0.12	4
S27	Die design change request input if any from die design	1	1	1	0	1	0.14	4	0.15	5
S28	Is this a minor FCO change ?	1	0	1	0	0	0.08	2	0.08	2
S29	Die line-up review with plant and senior manufacturing engineer	1	4	1	0	0	0.22	7	0.17	5
S30	Die processing tracking database (for scheduling)	0	0	1	0	0.5	0.05	1	0.06	1
S31	"Make any required change, if needed"	1	2	1	0	0.5	0.16	5	0.15	5
S32	Sign-off	0	0.5	1	0	0	0.05	1	0.05	0
S33	Is this a pre-die processing phase?	1	0	1	0	0	0.08	2	0.08	2
S34	Provide final die line-ups and MM drawings to layout	1	0	1	0	1	0.10	3	0.13	4
S36	Ship line-ups and MM drawings to car platform group	1	1	1	0	1	0.14	4	0.15	5
S37	Update tracking database (a PC-based system)	0	0.25	1	0	1	0.07	1	0.09	2

Figure 7 Value graph of quality characteristics



is intended to better meet customers changing requirements, increase organizational capabilities, and at the same time, maximize company goals.

Concluding remarks

The paper has extended the initial idea of combining market research data with QFD to include value engineering. By integrating TIRs and CIRs with value engineering and value graphs, product designers can obtain priorities (relative preferences) on QC functions. The use of QFD with value engineering gives the customers not only what they consider important but the priorities of building such quality characteristics into the product based on a number of considerations, which are essential to the company, the customers, and the organization (extended supply chain) as a whole.

The QFD-based value engineering approach lets a product designer prioritize the product improvement solutions, to meet the needs of the entire value-chain continuum – customers, the company, and the suppliers. The template can be used for carrying out the following value-based synthesis:

(1) Assess how an organization perceives its product ranks relative to its competitor (technical competitive assessment).
(2) Prioritize ratings that identify relative importance of each of the product solutions (quality characteristics).
(3) Prioritize how a competitor's product performs relative to each of the chosen quality characteristics (benchmark data).
(4) Compute weighted sum of QCs with respect to both the customer preferences and those based on value engineering.

The value-based template synthesis can also be used to pinpoint whether or not a technological solution is sufficient and where new manufacturing research would be necessary. By varying the appropriate combinations of product solutions in such a way that a set of computed TIRs lies within a value-based TIRs' bounds ensures that the product solution in question meets all requirements.

References

Akao, Y.A. (1990), *Quality Function Deployment – Integrating Customer Requirements into Product Design*, Productivity Press, Cambridge, MA. Also in *Quality Deployment*, a series of articles edited by Akao, Y.A., Japanese Standards Association and translated by Mazur, G.H., GOAL/QPC, Methuen, MA.

ASQC (American Society for Quality Control) (1992), Automotive Division, American Supplier Institute (ASI), GOAL/QPC, *Transactions from the Fourth Symposium on Quality Function Deployment (QFD)*, 15-16 June, Novi, MI.

Bascaran, E. (1991), "Design through selection: the use of QFD in the attribute generation process", *Design Theory and Methodology Conference*, Vol. DE-31, ASME Press, New York, NY.

Bossert, J.L. (1991), *Quality Function Deployment: A Practitioner's Approach*, ASQC Quality Press, Milwaukee, WI.

Clark, K.B. and Fujimoto, T. (1991), *Product Development Performance*, Harvard Business School Press, Boston, MA.

Clausing, D.P. (1994), *Total Quality Development: A Step-by-step Guide to World-Class Concurrent Engineering*, ASME Press, New York, NY.

Clausing, D.P. and Pugh, S. (1991), "Enhanced quality function deployment", *Design and Productivity International Conference*, 6-8 February, Honolulu, HA. Also in *Enhanced QFD Workshop*, seminar conducted at General Physics Corp., 17-18 April, Troy, MI.

Day, R.G. (1993), "Using quality function deployment in the product development process", *The Journal of Applied Manufacturing Systems*, Autumn.

Deming, W.E. (1986), *Out of Crisis*, 2nd ed., MIT Center for Advanced Engineering Study, Cambridge MA.

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

Dika, R.J. and Begley, R.L. (1991), "Concept development through teamwork – working for quality, cost, weight and investment ", SAE Paper # 910212, *Proceedings of the SAE International Congress and Exposition*, 25 February-1March, SAE, Detroit, MI, pp. 1-12.

Evbuomwan, N.F.O. and Sivaloganathan, S. (1994), "The nature, classification and management of tools and resources for concurrent engineering", in Paul, A.J. and Sobolewski, M. (Eds), *Proceedings of the Ist International Conference on Concurrent Engineering: Research & Applications*, 29-31 August, Pittsburgh, PA, pp. 119-26.

Evbuomwan, N.F.O., Sivaloganathan, S. and Jebb, A. (1994), "Concurrent design with design function deployment", *Proceedings of the 2nd International Conference on Concurrent Engineering and Electronic Design Automation*, Haven Hotel, Poole, 7-8 April.

Griffin, A. and Hauser, J.R. (1991), "The voice of the customer", Working Paper, Sloan School of Management of the Massachusetts School of Management, Cambridge, MA.

Hales, R., Lyman, D. and Norman, R. (1990), "Quality function deployment and the expanded house of quality", International TechneGroup Inc., Technical Report, OH, pp. 1-12.

Harr, S., Clausing, D.P. and Eppinger, S.D. (1993), "Integration of quality function deployment and the design structure matrix", Working Paper No. LMP-93-004, Laboratory for Manufacturing and Productivity, Massachusetts Institute of Technology, Cambridge, MA.

Hauser, J.R. and Clausing, D.P. (1988), "The house of quality", *Harvard Business Review*, Vol. 66 No. 3, May-June, pp. 63-73.

King, B. (1989), *Better Designs in Half the Time – Implementing QFD Quality Function Deployment in America*, 3rd ed., GOAL/QPC, Methuen, MA.

Liner, M. (1992), "First experiences using QFD in new product development", in Agogino, A. (Ed.), *Design for Manufacture*, *Proceedings of the Winter Annual Meeting of ASME*, Anaheim, CA, Vol. DE-51, 8-13 November, ASME Press, New York, NY.

Locascio, A. and Thurston, D.L. (1993), "Multiattribute design optimization using QFD", in Mitta, D.A. *et al.* (Eds), *Proceedings of the 2nd Industrial Engineering Research Conference*, Industrial Engineering and Management Press, Norcross, GA.

Masud, A.S.M. and Dean, E.B. (1993), "Using fuzzy sets in quality function deployment", in Mitta, D.A. *et al.* (Eds), *Proceedings of the 2nd Industrial Engineering Research Conference*, Industrial Engineering and Management Press, Norcross, GA.

Mizuno, S. and Akao, Y. (1994), *QFD: The Customer-driven Approach to Quality Planning and Deployment*, Asian Productivity Organization, Tokyo.

Prasad, B. (1993), "Product planning optimization using quality function deployment", Chapter 5 in *AI in Optimal Design and Manufacturing*, edited by Dong, Z. and series editor Jamshidi, M., Prentice-Hall, Englewood Cliffs, NJ, pp. 117-52.

Prasad, B. (1996), *Concurrent Engineering Fundamentals: Integrated Product and Process Organization*, Vol. 1, Prentice Hall PTR, Upper Saddle River, NJ.

Prasad, B. (1997), *Concurrent Engineering Fundamentals: Integrated Product Development*, Vol. 2, Prentice Hall PTR, Upper Saddle River, NJ.

Prasad, B. (1998), "Review of QFD and related deployment techniques", *Journal of Manufacturing Systems*, Society of Manufacturing Engineers (SME), May/June (in Press), Dearborn, MI.

Prasad, B. and Strand, N. (1993), "A flow-chart-based methodology for process improvement", in *Quality Concepts '93 World Class Manufacturing*, Engineering Society of Detroit, pp. 53-74.

Pugh, S. (1991), *Total Design-Integrating Methods for Successful Product Engineering*, Addison Wesley, Wokingham.

Roberts, L. (1994), *Process Re-engineering: The Key to Achieving Breakthrough Success*, ASQC Quality Press, Milwaukee, WI.

Ross, P.J. (1988), "The role of Taguchi methods and design of experiments in QFD", *Quality Program*, June, pp. 41-7.

Scheurell, D.M. (1992), "Concurrent engineering and the entire QFD process: one year after start-up of a new mill", *Transactions of the Fifth Symposium on Quality Function Deployment*, QFD Institute, Novi, MI (co-sponsored by ASI and GOAL/QPC).

Shillito, M.L. (1994), *Advanced QFD – Linking Technology to Market and Company Needs*, John Wiley and Sons, New York, NY.

Sivaloganathan, S. and Evbuomwan, N.F.O. (1997), "Quality function deployment – the technique: state of the art and future directions", *Concurrent Engineering: Research & Applications*, special issue on Enterprise Integration and Management in CE II, guest editors: Gunasekaran and Sarhadi, Vol. 5 No. 2, June, pp. 171-82.

Taguchi, G. and Clausing, D.P. (1990), "Robust quality", *Harvard Business Review*, Vol. 68 No. 1, January-February, pp. 65-75.

Taguchi, S. (1987), *Taguchi Methods and QFD: HOWs and WHYs for Management*, American Supplier Institute, ASI Press, Dearborn, MI.

Terninko, J. (1997), *Step-by-Step QFD Customer Driven Product Design*, 2nd ed., Boca CRC Press LLC (imprint St. Lucie Press), Raton, FL.

Ungvari, S. (1991), "Total quality management and quality function deployment", *Proceedings of the 3rd Symposium on Quality Function Deployment*, 24-25 June, Michigan.

Wilson, P.M. and Greaves, J.G. (1990), "Forward engineering – a strategic link between design and profit", *Mechatronic Systems Engineering*, Vol. I, pp. 53-64.

Qualitative Market Research: An International Journal
Volume 1 · Number 3 · 1998 · 156–172

Appendix

Table AI Summary of the various concepts or methodologies used in the paper

Concepts/ methodologies	Descriptions	Purpose and benefits
Voice of the customers (VOCs)	Voices come from different types of customers. Customers who do not buy a company's product also have a voice. This means VOCs include internal, external customers, as well as past and future customers	VOCs let you understand what it takes to satisfy different types of customers' interests
Quality characteristics (QCs)	QCs represent a list of design features, functions, qualities, etc. a future product should possess. This represents a HOW vector in HOQ	QCs help a company to identify what features (bells and whistles) to design into a product
Quality function deployment (QFD)	QFD is Customer-driven Product Development methodology to incorporate "voice of the customers" into all phases of the product development cycle. QFD systematically captures product information, such as, market competitive analysis and customer satisfaction ratings	QFD lets a company analyze these ratings to improve product functionality to reduce product development cycle-time and then to add values which are important to both the customers and the companies
House of quality (HOQ)	The basic matrix of QFD is the "house of quality (HOQ)", so named since the triangular matrix, which forms its top structure – the roof, makes the diagram resembles a house	HOQ helps deploy customer wants and needs into the appropriate design and delivery functions within one's organization
Product development teams (PDTs)	PDT is a multi-disciplinary setup – generally composed of several distinct technical sub-units specializing in a variety of disciplines	Multi-functional teams bring specialized knowledge necessary for the execution of the program
Competitive product assessments	Customers are asked to rate the requirements (WHATs) of a competitor product. They are asked to identify what they liked in a competitor product and what they did not like including their preferences of product's requirements with respect to each other	Competitor product assessment charts are used to assess two things: rate the requirement of a competitive product and rate the quality characteristics for the same competitor's product
Company product assessment	Customers are asked to rate the QCs (HOWs) of a company product. They are asked to identify what QCs they liked in a company product and what they did not like including their collective preferences or choices	Competitor product and company product assessment charts are used in HOQ to compare the requirements and the QCs of a competitor product with a company product
Technical importance ratings (TIRs)	TIRs are the results of calculations from the QFD house of quality matrix defined earlier	Technical importance ratings are used to determine which of the QCs should receive the most resources and which are particularly useful in evaluating alternative designs
Customer importance ratings (CIRs)	CIRs are derived from the field or customer surveys. The customers are required to rate the requirements (WHATs) and prioritize the importance of each with respect to the rest	It allows product developers to assign priorities – what potential customers would consider important in a future product and what they would not
Market research data	Market research data are commonly obtained from the following four sources: voice of the customers (VOCs), product data, warranty or field data, and competitive analysis data	It enables a company to choose products and features that the consumers would want, would like and will buy, if available
Value engineering	Value engineering is a method of analyzing a process, identifying the value attributes that are associated with it and eliminating waste. There are three types of values used in value engineering: customer perceived value, process value, and company-perceived value	The main idea is to study the functional worth of each activity in a process and to analyze whether an activity is adding any value to a product system or not
Value graphs	The points on the value graph represent the value index for each of the QCs. The value points, which fall on the diagonal line (slope =1) represent a break-even point. The ponts which fall below the unit slope line, represent the good points	The points, which fall above the unit slope line, represent the areas of possible improvements in performance or efficiency
Concurrent engineering (CE)	CE is a paralleled approach – replacing the time-consuming linear process of serial engineering and expensive prove-outs	It is intended to elicit the product developers, from the outset, to consider the "total job" (including company's support functions).
Synthesis of market research data	This involves performing market research, analyzing the data (ratings) with QFD, synthesizing results with value engineering and plotting them using value graphs. The QFD analysis initially results in the computations of technical importance ratings (TIRs) and customer importance ratings (CIRs). The initial QFD rating analysis is followed by a synthesis of the two based on value engineering	The major goals of this synthesis are to incorporate customer voice during early design stages, improve quality, functionality (X-ability), innovations (tools and technology), responsiveness and upgrade enterprise infrastructure