Quality Function Deployment

INTRODUCTION

Quality must be designed into the product, not inspected into it. Quality can be defined as meeting customer needs and providing superior value. This focus on satisfying the customer's needs places an emphasis on techniques such as Quality Function Deployment to help understand those needs and plan a product to provide superior value.

Quality Function Deployment (QFD) is a structured approach to defining customer needs or requirements and translating them into specific plans to produce products to meet those needs. The "voice of the customer" is the term to describe these stated and unstated customer needs or requirements. The voice of the customer is captured in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, etc. This understanding of the customer needs is then summarized in a product planning matrix or "house of quality". These matrices are used to translate higher level "what's" or needs into lower level "how's" - product requirements or technical characteristics to satisfy these needs.

While the Quality Function Deployment matrices are a good communication tool at each step in the process, the matrices are the means and not the end. The real value is in the process of communicating and decision-making with QFD. QFD is oriented toward involving a team of people representing the various functional departments that have involvement in product development: Marketing, Design Engineering, Quality Assurance, Manufacturing/ Manufacturing Engineering, Test Engineering, Finance, Product Support, etc.

The active involvement of these departments can lead to balanced consideration of the requirements or "what's" at each stage of this translation process and provide a mechanism to communicate hidden knowledge - knowledge that is known by one individual or department but may not otherwise be communicated through the organization. The structure of this methodology helps development personnel understand essential requirements, internal capabilities, and constraints and design the product so that everything is in place to achieve the desired outcome - a satisfied customer. Quality Function Deployment helps development personnel maintain a correct focus on true requirements and minimizes misinterpreting customer needs. As a result, QFD is an effective communications and a quality planning tool.

CAPTURING THE VOICE OF THE CUSTOMER

The process of capturing the voice of the customer is described in the papers on Product Definition and Steps for Performing QFD. It is important to remember that there is no one monolithic voice of the customer. Customer voices are diverse. In consumer markets, there are a variety of different needs. Even within one buying unit, there are multiple customer voices (e.g., children versus parents). This applies to industrial and government markets as well. There are even multiple customer voices within a single organization: the voice of the procuring organization, the voice of the user, and the voice of the supporting or maintenance organization. These diverse voices must be considered, reconciled and balanced to develop a truly successful product. One technique to accomplish this is to use multiple columns for different priority ratings associated with each customer voice in the product planning matrix.
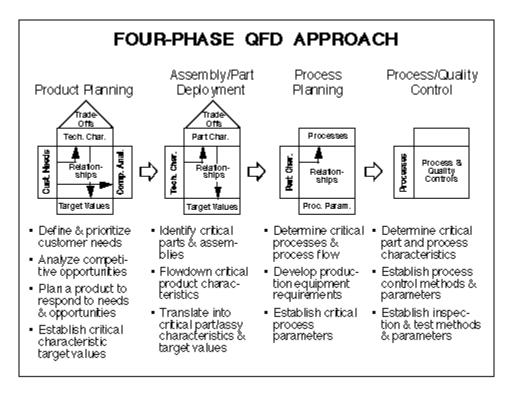
Quality Function Deployment requires that the basic customer needs are identified. Frequently, customers will try to express their needs in terms of "how" the need can be satisfied and not in terms of "what" the need is. This limits consideration of development alternatives. Development and marketing personnel should ask "why" until they truly understand what the root need is. Breakdown general requirements into more specific requirements by probing what is needed.

Once customer needs are gathered, they then have to be organized. The mass of interview notes, requirements documents, market research, and customer data needs to be distilled into a handful of statements that express key customer needs. Affinity diagramming is a useful tool to assist with this effort. Brief statements which capture key customer requirements are transcribed onto cards. A data dictionary which describes these statements of need are prepared to avoid any misinterpretation. These cards are organized into logical groupings or related needs. This will make it easier to identify any redundancy and serves as a basis for organizing the customer needs for the first QFD matrix.

In addition to "stated" or "spoken" customer needs, "unstated" or "unspoken" needs or opportunities should be identified. Needs that are assumed by customers and, therefore not verbalized, can be identified through preparation of a function tree. These needs normally are not included in the QFD matrix, unless it is important to maintain focus on one or more of these needs. Excitement opportunities (new capabilities or unspoken needs that will cause customer excitement) are identified through the voice of the engineer, marketing, or customer support representative. These can also be identified by observing customers use or maintain products and recognizing opportunities for improvement.

QFD METHODOLOGY FLOW

The basic Quality Function Deployment methodology involves four basic phases that occur over the course of the product development process. During each phase one or more matrices are prepared to help plan and communicate critical product and process planning and design information. This QFD methodology flow is represented below.

PRODUCT PLANNING USING QFD

Once customer needs are identified, preparation of the product planning matrix or "house of quality" can begin. The sequence of preparing the product planning matrix is as follows:

1. Customer needs or requirements are stated on the left side of the matrix as shown below. These are organized by category based on the affinity diagrams. Insure the customer needs or requirements reflect the desired market segment(s). Address the unspoken needs (assumed and excitement capabilities). If the number of needs or requirements exceeds twenty to thirty items, decompose the matrix into smaller modules or subsystems to reduce the number of requirements in a matrix. For each need or requirement, state the customer priorities using a 1 to 5 rating. Use ranking techniques and paired comparisons to develop priorities.

2. Evaluate prior generation products against competitive products. Use surveys, customer meetings or focus groups/clinics to obtain feedback. Include competitor's customers to get a balanced perspective. Identify price points and market segments for products under evaluation. Identify warranty, service, reliability, and customer complaint problems to identify areas of improvement. Based on this, develop a product strategy. Consider the current strengths and weaknesses relative to the competition? How do these strengths and weaknesses compare to the customer priorities? Where does the gap need to be closed and how can this be done - copying the competition or using a new approach or technology? Identify opportunities for breakthrough's to exceed competitor's capabilities, areas for improvement to equal competitors capabilities, and areas where no improvement will be made. This strategy is important to focus development efforts where they will have the greatest payoff.

3. Establish product requirements or technical characteristics to respond to customer requirements and organize into related categories. Characteristics should be meaningful, measurable, and global. Characteristics should be stated in a way to avoid implying a particular technical solution so as not to constrain designers.

4. Develop relationships between customer requirements and product requirements or technical characteristics. Use symbols for strong, medium and weak relationships. Be sparing with the strong relationship symbol. Have all customer needs or requirement been addressed? Are there product requirements or technical characteristics stated that don't relate to customer needs?

5. Develop a technical evaluation of prior generation products and competitive products. Get access to competitive products to perform product or technical benchmarking. Perform this evaluation based on the defined product requirements or technical characteristics. Obtain other relevant data such as warranty or service repair occurrences and costs and consider this data in the technical evaluation.

6. Develop preliminary target values for product requirements or technical characteristics.

7. Determine potential positive and negative interactions between product requirements or technical characteristics using symbols for strong or medium, positive or negative relationships. Too many positive interactions suggest potential redundancy in "the critical few" product requirements or technical characteristics. Focus on negative interactions - consider product concepts or technology to overcome these potential tradeoff's or consider the tradeoff's in establishing target values.

8. Calculate importance ratings. Assign a weighting factor to relationship symbols (9-3-1, 4-2-1, or 5-3-1). Multiply the customer importance rating by the weighting factor in each box of the matrix and add the resulting products in each column.

9. Develop a difficulty rating (1 to 5 point scale, five being very difficult and risky) for each product requirement or technical characteristic. Consider technology maturity, personnel technical qualifications, business risk, manufacturing capability, supplier/subcontractor capability, cost, and schedule. Avoid too many difficult/high risk items as this will likely delay development and exceed budgets. Assess whether the difficult items can be accomplished within the project budget and schedule.

10. Analyze the matrix and finalize the product development strategy and product plans. Determine required actions and areas of focus. Finalize target values. Are target values properly set to reflect appropriate tradeoff's? Do target values need to be adjusted considering the difficulty rating? Are they realistic with respect to the price points, available technology, and the difficulty rating? Are they reasonable with respect to the importance ratings? Determine items for further QFD deployment. To maintain focus on "the critical few", less significant items may be ignored with the subsequent QFD matrices. Maintain the product planning matrix as customer requirements or conditions change.

One of the guidelines for successful QFD matrices is to keep the amount of information in each matrix at a manageable level. With a more complex product, if one hundred potential needs or requirements were identified, and these were translated into an equal or even greater number of product requirements or technical characteristics, there would be more than 10,000 potential relationships to plan and manage. This becomes an impossible number to comprehend and manage. It is suggested that an individual matrix not address more than twenty or thirty items on each dimension of the matrix. Therefore, a larger, more complex product should have its customers needs decomposed into hierarchical levels.

To summarize the initial process, a product plan is developed based on initial market research or requirements definition. If necessary, feasibility studies or research and development are undertaken to determine the feasibility of the product concept. Product requirements or technical characteristics are defined through the matrix, a business justification is prepared and approved, and product design then commences.

CONCEPT SELECTION AND PRODUCT DESIGN

Once product planning is complete, a more complete specification may be prepared. The product requirements or technical characteristics and the product specification serve as the basis for

developing product concepts. Product benchmarking, brainstorming, and research and development are sources for new product concepts. Once concepts are developed, they are analyzed and evaluated. Cost studies and trade studies are performed. The concept selection matrix can be used to help with this evaluation process.
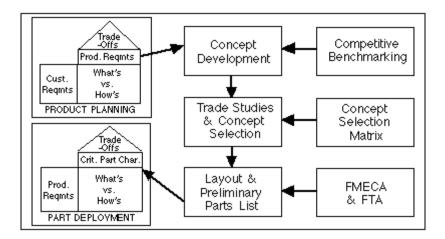
The concept selection matrix shown below lists the product requirements or technical characteristics down the left side of the matrix.

Criteria	Importance Rating	Concept A		Concept B		Concept C	
Low APU Weight	4	◉	20	○	12	○	12
Low turbine wheel weight	4	◉	20	○	12	◉	20
Controlled turbine inlet temperature	6	○	18	◉	30	△	6
Acceptable turbine assembly life	5	○	15	◉	25	○	15
Turbine assy tri-hub containment	5	◉	25	◉	25	○	15
High equivalent shaft horsepower	4	△	4	◉	20	◉	20
Strong internal containment ring	4	○	12	◉	20	○	12
Total			114		144		100

These serve as evaluation criteria. The importance rating and target values (not shown) are also carried forward and normalized from the product planning matrix. Product concepts are listed across the top. The various product concepts are evaluated on how well they satisfy each criteria in the left column using the QFD symbols for strong, moderate or weak. If the product concept does not satisfy the criteria, the column is left blank. The symbol weights (5-3-1) are multiplied by the importance rating for each criteria. These weighted factors are then added for each column. The preferred concept will have the highest total. This concept selection technique is also a design synthesis technique. For each blank or weak symbol in the preferred concept's column, other concept approaches with strong or moderate symbols for that criteria are reviewed to see if a new approach can be synthesized by borrowing part of another concept approach to improve on the preferred approach.

Based on this and other evaluation steps, a product concept is selected. The product concept is represented with block diagrams or a design layout. Critical subsystems, modules or parts are identified from the layout. Criticality is determined in terms of effect on performance, reliability, and quality. Techniques such as fault tree analysis or failure modes and effects analysis (FMEA) can be used to determine criticality from a reliability or quality perspective.

The subsystem, assembly, or part deployment matrix is then prepared. The process leading up to the preparation of the deployment matrix is depicted below.

The product requirements or technical characteristics defined in the product planning matrix become the "what's" that are listed down the left side of the deployment matrix along with priorities (based on the product planning matrix importance ratings) and target values. The deployment matrix is prepared in a manner very similar to the product planning matrix. These product requirements or technical characteristics are translated into critical subsystem, assembly or part characteristics. This translation considers criticality of the subsystem, assembly or parts as well as their characteristics from a performance perspective to complement consideration of criticality from a quality and reliability perspective. Relationships are established between product requirements or technical characteristics and the critical subsystem, assembly or part characteristics. Importance ratings are calculated and target values for each critical subsystem, assembly or part characteristic are established. An example of a part/assembly deployment matrix is shown:

PROCESS DESIGN

Quality Function Deployment continues this translation and planning into the process design phase. A concept selection matrix can be used to evaluate different manufacturing process approaches and select the preferred approach. Based on this, the process planning matrix shown below is prepared.

Critical Process Steps	Turbine wheel					Rating	Part Control Parameters
	Balanced	Surface finish	Backface geometry	Grain refinement	Airfoil geo. & thickness		
Priority	2	4	4	9	5		
Mold preparation	○	◎			◎	51	- surface finish - airfoil geometry
Hot isostatic pressure casting	○	◎		◎	◎	96	- surface finish - inclusions, cracks, porosity - Blade tip fill
Mass center balancing	◎					10	- Machine centers
Turbine tip OD & shroud line contour machining		○				12	- outer diameter - Profile geometry - surface finish
Low stress grind – backface	○	◎	◎			46	- Backface geometry - surface finish

Other Data:
- Equipment
- Location
- Tooling

Again, the "how's" from the higher level matrix (in this case the critical subsystem, assembly or part characteristics) become the "what's" which are used to plan the process for fabricating and assembling the product. Important processes and tooling requirements can be identified to focus efforts to control, improve and upgrade processes and equipment. At this stage, communication between Engineering and Manufacturing is emphasized and tradeoff's can be made as appropriate to achieve mutual goals based on the customer needs.

In addition to planning manufacturing processes, more detailed planning related to process control, quality control, set-up, equipment maintenance and testing can be supported by additional matrices. The following provides an example of a process/quality control matrix.

Critical Process Steps	Process Control Parameters	Control Points	Control Method	Sample Size & Freq.	Check Method
Hot isostatic pressure casting	Mat'l temp. Mold temp. Remelt %	Mat'l prop. Heat treat FPI	Cert.	100%	N/A
Mass center balancing	Balance mach. calibration Speed	Detailed balance	Cert.	100%	N/A
Turbine tip OD & shroud line contour machining	Set-up Speeds & feeds Tool wear	Dim. insp. Surface finish	X bar & R chart	4 pieces/lot	Elect. gage Check fixture Visual
Low stress grind – backface	Speeds & feeds Diamond dressed wheel	Dim. insp. Surface finish	N/A	100%	CMM Visual
Florescent penetrant insp. & proof spin	Speed	Cracks Inclusions O.D.	N/A	100%	Visual Spin test

The process steps developed in the process planning matrix are used as the basis for planning and defining specific process and quality control steps in this matrix.

The result of this planning and decision-making is that Manufacturing focuses on the critical processes, dimensions and characteristics that will have a significant effect on producing a product that meets customers needs. There is a clear trail from customer needs to the design and manufacturing decisions to satisfy those customer needs. Disagreements over what is important at each stage of the development process should be minimized, and there will be greater focus on "the critical few" items that affect the success of the product.

QFD PROCESS

Quality Function Deployment begins with product planning; continues with product design and process design; and finishes with process control, quality control, testing, equipment maintenance, and training. As a result, this process requires multiple functional disciplines to adequately address this range of activities. QFD is synergistic with multi-function product development teams. It can provide a structured process for these teams to begin communicating, making decisions and planning the product. It is a useful methodology, along with product development teams, to support a concurrent engineering or integrated product development approach .

Quality Function Deployment, by its very structure and planning approach, requires that more time be spent up-front in the development process making sure that the team determines, understands and agrees with what needs to be done before plunging into design activities. As a result, less time will be spent downstream because of differences of opinion over design issues or redesign because the product was not on target. It leads to consensus decisions, greater commitment to the development effort, better coordination, and reduced time over the course of the development effort.

QFD requires discipline. It is not necessarily easy to get started with. The following is a list of recommendations to facilitate initially using QFD.

- Obtain management commitment to use QFD.
- Establish clear objectives and scope of QFD use. Avoid first using it on a large, complex project if possible. Will it be used for the overall product or applied to a subsystem, module, assembly or critical part? Will the complete QFD methodology be used or will only the product planning matrix be completed?
- Establish multi-functional team. Get an adequate time commitment from team members.
- Obtain QFD training with practical hands-on exercises to learn the methodology and use a facilitator to guide the initial efforts.
- Schedule regular meetings to maintain focus and avoid the crush of the development schedule overshadowing effective planning and decision-making.
- Avoid gathering perfect data. Many times significant customer insights and data exist within the organization, but they are in the form of hidden knowledge - not communicated to people with the need for this information. On the other hand, it may be necessary to spend additional time gathering the voice of the customer before beginning QFD. Avoid technical arrogance and the belief that company personnel know more than the customer.

Quality Function Deployment is an extremely useful methodology to facilitate communication, planning, and decision-making within a product development team. It is not a paperwork exercise or additional documentation that must be completed in order to proceed to the next development milestone. It not only brings the new product closer to the intended target, but reduces development cycle time and cost in the process.

ABOUT THE AUTHOR

KENNETH A. CROW is President of DRM Associates and a Principal in PD-Trak Solutions. His firm focuses on improving product development and the implementation of strategies and practices such as integrated product development, time-to-market, and business process re-engineering for the high technology, capital equipment, medical equipment, transportation equipment, aerospace and defense industries. He is a recognized expert in the field of integrated product development and quality function deployment with over twenty years of experience organizing and guiding product development improvement programs and assisting product development teams. He led a consortium to identify 270 best practices or product development and developed a benchmarking and assessment methodology based on these best practices.

Ken has worked internationally with many Fortune 500 companies. He has written articles and papers, contributed to books, presented at conferences, and conducted workshops in Australia, North America, Europe and Asia on product development, manufacturing, and quality function deployment. He is a certified New Product Development Professional through PDMA. He is a founding member and past President of the Society of Concurrent Engineering and is a member of the Product Development Management Association and the Engineering Management Society. For further information, contact Ken at DRM Associates, 2613 Via Olivera, Palos Verdes, CA 90274; by phone at (310) 377-5569; by fax at (310) 377-1315 or by email at kcrow@aol.com.