# QFD: ECHOING THE VOICE OF THE CUSTOMER

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One of the most promising techniques in contemporary, customer-driven engineering is quality-function deployment (QFD). This product-realization approach helps ensure that customer needs and expectations directly influence the definition, design, implementation, and deployment of products and services. QFD comprises a system of highly traceable engineering procedures in a cross-functional team framework that use graphical displays to drive all phases of product deployment without stifling the voice of the customer. QFD-based product realization yields clear competitive advantages over more traditional processes by promoting greater customer satisfaction, shorter time to market, and improved product performance. Within AT&T, QFD has been used in such diverse applications as planning software-development environments, specifying the characteristics of transmission systems, and guiding the definition of more tangible products like batteries. This paper highlights the QFD process, drawing examples from recent projects that used QFD in refining a software-development environment and in realizing computing services.



## Introduction

Quality-function deployment (QFD) is a quality-assurance system that helps ensure that the *voice of the customer*—the specific needs and desires of a given customer segment—is clearly heard and followed in the development and deployment of a product or service. (Panel 1 defines acronyms and terms used in this paper.)

Besides responding more precisely to customer needs, producers can respond more quickly using QFD than they can with traditional product-realization strategies, thus gaining faster market penetration and larger market share.[1,2] The overall results? Greater

**Panel 1. Abbreviations and Terms in This Paper**

affinity grouping — a team-based consensus technique for organizing information (e.g., WHATs) into hierarchical clumps.

HOQ — house of quality, the highest-level QFD matrix; it displays customer wants versus the design requirements necessary to meet them. Related product-definition information (e.g., customer importance, competitive position, etc.) is also displayed.

HOW — a QFD term for a mechanism that fulfills a WHAT. In the first phase of QFD, these are the first-level technical attributes of a product or service that explicitly address customer needs or wants.

HOW MUCH — a QFD term for the target value of a HOW.

KETC — AT&T Bell Laboratories' Kelly Education and Training Center.

MR — modification request.

product — the output of a process. A product may be a tangible item such as a telephone set, or an ongoing process such as computing-environment support. Also, products may be *internal* (i.e., intended for use by subsequent processes within the organization) or *external* (i.e., intended for transfer to a customer outside the organization).

product-realization cycle — product-development life cycle; the process of bringing a product into existence, from inception through deployment to customers.

QFD — quality-function deployment; a team-based, graphically oriented system for stepwise product realization explicitly driven by the voice of the customer.

QPC — Quality Process Center.

VOC — voice of the customer; a customer need, want, expectation, or concern. As input to QFD, VOC data consists of untranslated statements of customer values; these can be verbatim statements from customers, or unfiltered observations about customer behavior.

WHAT — a QFD term for a statement of need or want. In the first phase of QFD, WHATs are the result of gathering VOC data. In subsequent phases of QFD, the needs of a product, process, or production facility are also thought of as WHATs. A WHAT is fulfilled by a HOW.

customer satisfaction, improved product performance, and enhanced profitability.

The key to QFD's competitive advantage is its structured application of four strategic concepts:

- *Preservation of the voice of the customer* ensures that customer needs won't be translated or distorted in the development process.
- A *cross-functional team* provides input to product realization from all areas of the business. Thus, the concerns of marketing, design, deployment, and support organizations are brought to the surface and dealt with early in the process.
- *Concurrent engineering* allows those parties, such as manufacturing, who have traditionally participated later in the product-realization cycle to begin planning earlier, using more accurate information. This shortens time-to-market.
- A concise *graphical display* presents a picture of the product that clearly links explicit customer needs to product-realization decisions.

Throughout this paper, *product* is used to denote any process output intended for consumption by a customer. Thus, it includes services, as well as goods.

### Development Processes, Old and New

In the United States, businesses have followed a traditional approach to product realization. But they have recently begun to use QFD, the approach that is a key

factor behind Japan's product-realization preeminence during the 1970s and 1980s.

**Traditional Product Realization.** In the United States, product realization has traditionally been characterized by these attributes:

- Each work group has its own ideas and methods.
- Product realization is highly sequential.
- Many development iterations are necessary.
- Design characteristics stray from customer intent.
- Everything is important.
- Designs meet tolerances, not targets.

Although they may be working toward realization of the same product, in the traditional approach, the different work groups use different terms and isolated procedures for adding their value to the product. Thus, there may be little common understanding among the groups.

Each party to the product-realization process adds value, in turn. Marketeers gather needs; systems engineers analyze these needs. Designers implement the solution concepts; testers verify the design. Builders manufacture the product; deployers put it in the field and support it. As a result, parallelism is very limited.



At each stage of the sequential process, instances of inadequate communication show up as product inadequacies, either from an internal- or external-customer perspective. The rework costs to correct these problems are high.

Skilled engineers, eager to apply their knowledge and abilities, are quick to translate customers' business needs into detailed technical solutions. Thus, the design characteristics stray from customer intent, and we quickly lose the customer's original perspective.

To us, all aspects of the product's design may seem equally important. Thus, we may try to address each of them in the best possible way, regardless of any aspect's importance to our customer. As a result, we dilute our resources. We may fail to meet key customer needs, while we attend to attributes that are of little significance to our customer.

A given product will be designed to function within a tolerance range, i.e., between theoretical minimum and maximum specification limits. As a result, designs meet tolerances, not explicit, customer-preferred operating targets. The additive effect of component tolerances that are close to limits may lead to failure, or the product as a whole may function poorly.

Figure 1a is a high-level view of the functions, owners, and flow of a product-realization process that is shaped by these characteristics. Obviously, in this process, each function adds its value in sequence, without explicit early knowledge of customer needs. The result is loss of customer perspective, suboptimization, serial communication, rework at each stage to correct misunderstandings, and delay in product availability.

**The QFD Approach.** In contrast, a product-development approach based on QFD has these characteristics:

- Cross-functional teams build a common understanding of the product.
- Product realization is more concurrent.
- Little, if any, rework is necessary.
- The voice of the customer is preserved in the design characteristics.
- Only those attributes that are key to customer satisfaction are important.
- Designs meet explicit operating targets, not theoretical specification tolerances.

Because the team encompasses the many functional areas involved in the development process, all the areas gain a common understanding of the product. The team members form a unifying product view through early interaction and consensus-based decision-making. (We will discuss the team concept in more detail later.)

With QFD, product realization is a concurrent process. Each of the parties gets a clear, early look at the product design. Familiarization occurs simultaneously, and communication is crisp and accurate throughout the cycle. As a result, little rework, if any, is necessary.

The deliverables (e.g., engineering drawings, computer programs, specification documents) that are

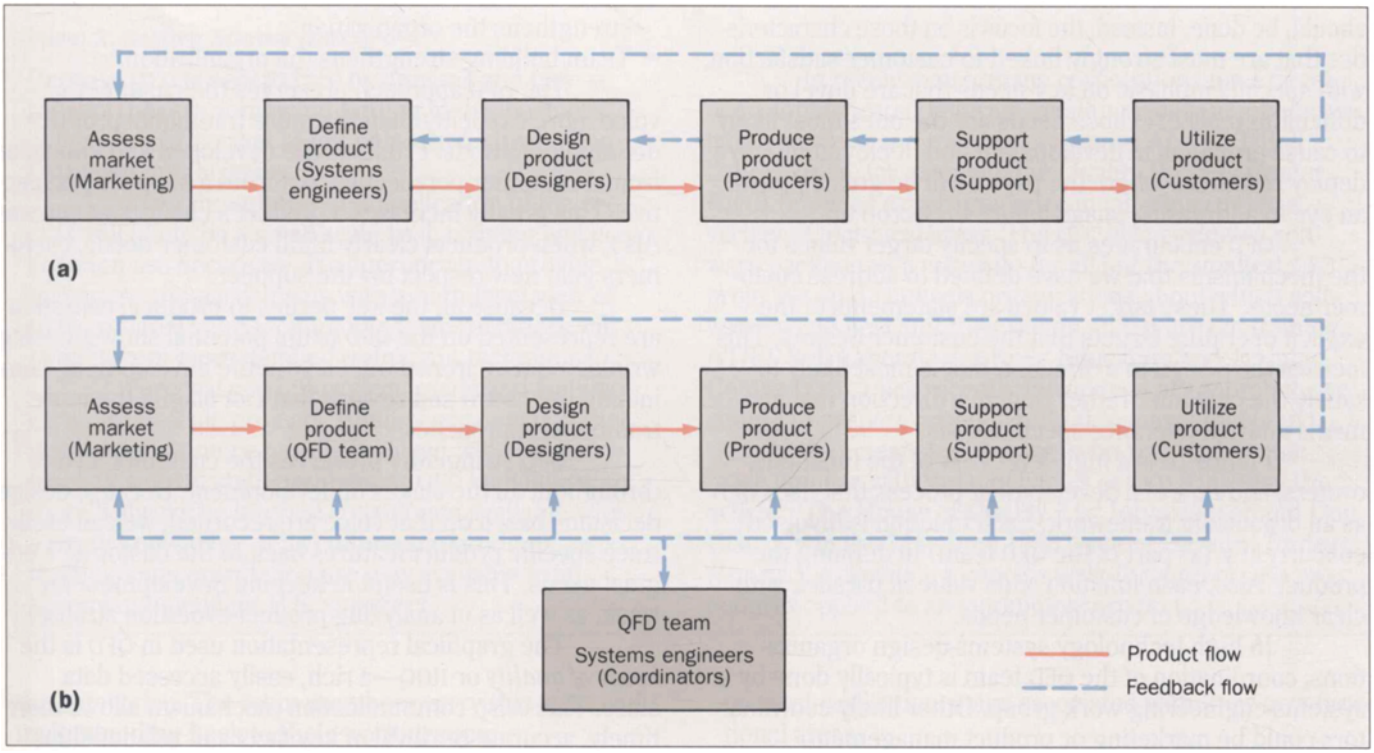


**Figure 1. The product-realization process. (a) In the traditional approach, each function adds its value in sequence, without explicit early knowledge of customer needs. (b) In a development process based on QFD, each function is involved concurrently as part of the team in defining the product and adds value in parallel, with clear knowledge of customer needs. Handoffs are crisp; rework is minimal. The process is optimized for the overall scope of product realization. Products reach market without undue delay, and with greater probability of customer satisfaction.**

handed off from function to function are the same in a QFD-based approach as they are in a more traditional approach. However, they're more likely to be complete and correct. This is the result of a cross-functional team that works with clear customer needs and a crisp data-organization structure (in the form of a graphical display). Because intent and details are well understood, surprises are rare. This obviates the need for rework of specifications and designs, reducing development time and increasing the probability that customers will get the product they want and need.

The QFD process emphasizes preservation of the customer's view at each step. The team uses special techniques to maintain this integrity during the processing of customer needs and the development of product specifications. In addition, QFD uses a graphical display whose structure ensures that the customer's voice can be traced throughout the development process.

QFD recognizes that not everything can, nor

should, be done. Instead, the focus is on those characteristics that are most strongly linked to customer satisfaction, with special emphasis on key needs that are novel or difficult to realize. (Those needs are the ones most likely to cause problems in development and deployment.) We deploy resources where the payoff will be greatest, with an eye to addressing snags before they crop up.

QFD encourages us to specify target values for the mechanisms that we have defined to address customer needs. These target values are statements of the explicit operating targets that the customer desires. This focuses the design in a direction that is most likely to satisfy the customer rather than in a direction that just meets internal tolerance specifications.

Figure 1b is a high-level view of the functions, owners, and flow of a development process that uses QFD as an organizing framework. Each function is involved concurrently (as part of the QFD team) in defining the product. Also, each function adds value in parallel, with clear knowledge of customer needs.



In high-technology systems-design organizations, coordination of the QFD team is typically done by a systems-engineering work group. Other likely coordinators could be marketing or product management.

With QFD, handoffs are crisp, rework is minimal, and the process is optimized for the overall scope of product realization. Products will reach market without undue delay, and the probability of customer satisfaction will be great.

**QFD versus Traditional Approaches.** The advantages of QFD over traditional product-realization processes include:

- Products meet real customer needs.
- QFD builds credibility with customers.
- Products reach market more quickly.
- QFD provides traceability of design intent.
- QFD provides a rich, accessible product-definition display (which will be discussed in detail later).
- Collective understanding of customer needs strengthens the organization.
- Team building strengthens the organization.

The QFD approach preserves the customer's voice more explicitly than the more traditional product-definition methods. Products are developed and enhanced from a customer perspective, not from a supplier perspective. This greatly increases a product's chances of success. Also, when products clearly fulfill customer needs, customers gain new respect for the supplier.

Because all the key parties to product realization are represented on the QFD team, potential show-stopping wrinkles can be ironed out early in the development, eliminating the churn and rework that can plague the more traditional approaches.

QFD stringently preserves the customer's voice throughout all the stages of development. Because design decisions based on that voice are recorded, we can easily trace specific product features back to the customer's original needs. This is useful in keeping development on track, as well as in analyzing product-evolution strategy.

The graphical representation used in QFD is the *house of quality* or HOQ—a rich, easily accessed data store. This crisp communication mechanism allows more timely, accurate retrieval of key facts and relationships than traditional development documentation (which is often voluminous and dispersed). The HOQ is also a comprehensive, efficient, training reference for employees who are new to the organization.

Core QFD team members, as well as others called in to help the team, gain profound knowledge of customer wants and of the functional perspectives of other team members. This spreads team-building awareness through the organization. After people have served on a QFD team, they typically feel strongly that they will be more effective in future product developments. They now *know* why and how customers use our products and what customers will value in the future.

As a result of their interactions, QFD team members build trust and understanding with other groups in

**Panel 2. Getting Started with QFD**

Because QFD is new to U.S. businesses and has aspects that are somewhat foreign to our business culture, it's important to get help when introducing QFD to an organization.

Even though the first application of the process will likely be a small-scale trial, training and consultation are necessary. It's appropriate to provide managers and participants with a high-level view of QFD's rationale and technology; team members will benefit from more-detailed training in techniques.

External consultants can guide and facilitate early, small-scale projects. But any organization that decides to get more heavily involved will benefit by training several staff members as QFD facilitators, so there'll always be internal consultants available with a ready knowledge of its culture and products. QFD training and consultation are now available from several independent U.S. suppliers.

In recent years, many corporations have developed sophisticated, internal, quality-management consultation services and training programs. At AT&T Bell Laboratories, for example, the Quality Process Center (QPC) provides expert guidance in tailoring QFD to a variety of technical areas. The QPC also evaluates software packages—a requisite for all but the smallest QFD projects—and counsels organizations about which software would best suit their needs. In the area of training, AT&T Bell Laboratories Kelly Education and Training Center (KETC) has recently introduced a comprehensive course to prepare product-definition teams to use QFD.

As a next step, readers who want to become more familiar with the mechanics of QFD will enjoy the article, "The House of Quality," by John Hauser and Don Clausing in the May-June 1988 issue of *Harvard Business Review*.[1] It provides a concise walk-through of QFD procedures applied to an automotive product.



the enterprise. The team members carry this trust and understanding back to their work groups.

### Elements of QFD

QFD has three key facets: a cross-functional *team* that operates in a structured *process* that is guided by a *graphical display*. Each facet can be scaled to meet the scope of a given project—adaptability is a hallmark of successful QFD application.

**The Team.** The QFD team comprises representatives from each of the major work groups involved in a product-realization process. Because this is a cross-functional team, each member brings special knowledge about the capabilities and requirements of his or her processes. Each member will gain a clear, intimate sense of customer values. This newly found collective understanding will enable members to identify potential product-realization snags associated with their own functional areas.

For as complex a product as a private-branch exchange, the team might include a marketing representative, systems engineer, project manager, circuit designer, software designer, system-assurance specialist, physical designer, manufacturing engineer, and product-support specialist. The team for a smaller product—such as a computer center's printing service—might have a systems engineer, software designer, system administrator, operations specialist, and customer-service representative. Additional consultants may be brought in as ad hoc team members.

Team members must have profound knowledge of their respective areas, and must be willing and able to serve on the team. They must also be empowered to make decisions that affect the product's eventual success

or failure in the marketplace. Teams meet often, typically from two to five times per week, depending on the type of project. With rare exception, each member must attend each meeting.

Teams operate by consensus. Thus, issues are discussed until a decision is reached that is supportable (though not necessarily favored) by each team member. There is usually a designated team leader, and often a QFD facilitator, to help keep the process moving.

**HOQ—The Graphical Display.** The QFD graphical display, which is called the *house of quality* because of its shape, provides a framework that guides the team through the QFD process. The HOQ is a matrix that contains information about customer values, mechanisms to address these values in the product, and criteria for deciding which of the mechanisms will provide the greatest customer satisfaction. Given the amount and variety of data, most QFD teams find it desirable to use a software package to assist in maintaining the HOQ. (Panel 2 offers suggestions for implementing the QFD process.)



Figure 2 depicts the structure of the HOQ; labels identify the different functional areas. The numbers in some areas of the matrix are index numbers that arbitrarily identify the rows and columns. The areas of this basic HOQ are:

- *WHAT*—identifies customer needs, which are grouped by topic areas.
- *Customer importance*—contains the customer-priority rating for each of the WHATs.
- *HOW*—identifies the mechanisms to fulfill the WHATs. These mechanisms are best stated as design requirements or as the technical characteristics of solutions, rather than as specific solutions.
- *Relationship matrix*—shows the relationships between the WHATs and the HOWs.
- *HOW MUCH*—contains target values for the HOWs.
- *Technical importance*—shows the customer-satisfaction effect of each HOW. Typically, the strength of each relationship is multiplied by the customer-importance rating. Then, each of the cell values in a given column is summed.
- *Correlation matrix*—shows the interactions among the HOWs.

Later, when we discuss the QFD process, we will provide details about how to fill in these areas.

Figure 3 shows selected WHATs and HOWs of a HOQ from an enterprise-planning project that was carried out by a software-technology provider. For this example, the HOWs have been arranged in decreasing order (using a QFD-support software package), according to their technical-importance ratings. This HOQ shows that HOWs #1 and #2 are particularly likely to contribute to fulfilling the WHATs shown, while HOW #16 would contribute hardly at all. Therefore, the QFD team recommended that #1 and #2 be put in place. But HOWs #4 and #5 were also selected because they earned very high ratings for other WHATs (which are not shown in this figure), in addition to scoring solidly here.

The team found no negative correlations among HOWs. However, there were some weak positive correlations, and one strong positive (i.e., providing HOW #11 might help them provide HOW #14, and vice versa).

Figure 3, as an example from an early QFD project, illustrates an area in which QFD practice has changed recently. In early projects in the United States, the HOWs in the highest-level matrix, the HOQ, were often stated as product *features*, i.e., specific technical solutions. While this can be valid, recent QFD experience has shown that it's more effective to state HOWs as less-constraining *design requirements* or *technical characteristics*. This maintains the HOQ as a *planning* matrix, which frees designers to choose from a broader range of explicit solutions in the phases that follow.

The HOQ for a given project may differ from those for other projects, depending on the product's complexity and the degree of analysis that the team chooses to undertake. In particular, many projects now include competitive-assessment information that is associated with the customer-importance data (e.g., how customers regard our product against specific competitors' offerings),

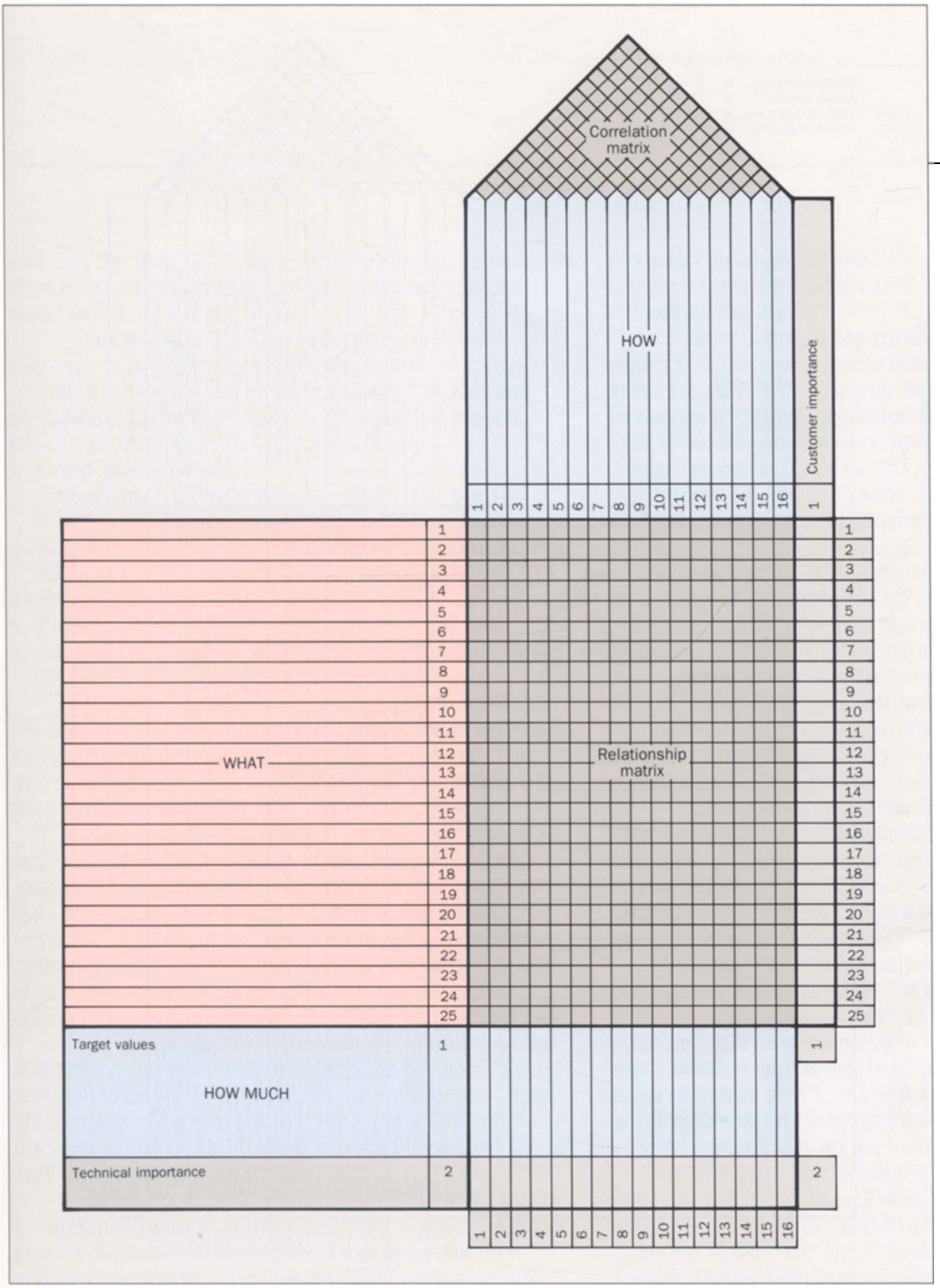


**Figure 2. Schematic view of a house of quality (HOQ). This matrix contains information about customer values (WHAT), the mechanisms (HOW) to address them in the product, and criteria (HOW MUCH and *technical importance*) for deciding which mechanisms will provide the greatest customer satisfaction. WHATs identify customer needs, while *customer importance* attaches a priority rating to each need. The *relationship matrix* shows the relationships between WHATs and HOWS; the *correlation matrix* shows interactions among HOWs.**

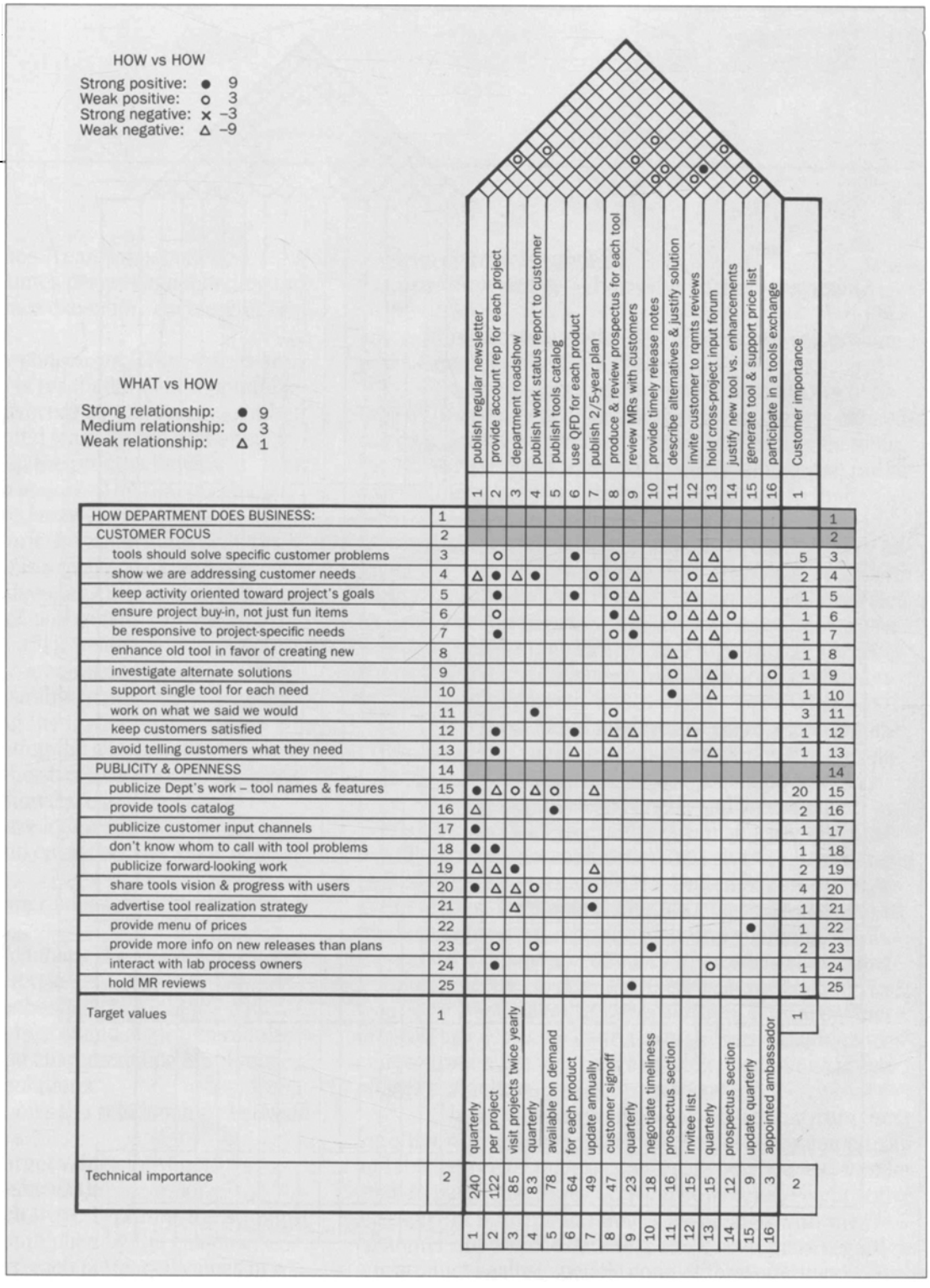


**Figure 3. Excerpt from a house of quality from a software-technology enterprise. The HOWs are arranged according to decreasing technical importance. HOWs #1 and #2 are most likely to help to fulfill the WHATs shown, while HOW #16 would contribute little. The QFD team recommended that HOWs #1 and #2 be put in place. They also selected HOWs #4 and #5, which had high ratings here and for other WHATs on the full HOQ.**

and with the HOW MUCH data (e.g., how well competitors do at achieving specific technical requirements, compared to us).

**The Process.** The QFD process is an orderly sequence of activities for processing customer values so that these values can directly shape the design and deployment of the product. The fundamental steps in the QFD process are:

1. Organize the project.
2. Gather and organize customer wants (i.e., the WHATs).
3. Establish mechanisms (i.e., the HOWs) and target values.
4. Establish relationships.
5. Evaluate the HOWs.
6. Analyze the house-of-quality matrix and finalize target values.

To *organize the project*, management establishes the project's scope and aims and, then, recruits representatives from all product-realization areas affected. The QFD facilitator or trainer familiarizes team members with the rationale, vocabulary, and techniques of QFD.

The team in now ready to *gather and organize the customer's wants* (the WHATs). First, the team collects statements that represent customer values, taking special care to avoid translating from customer terms into technical terms or jargon. The WHATs are gathered from customer-interview data, focus-group data, observations of customer-process satisfiers and dissatisfiers, customer-contact information, and other similar sources.

At this stage, some projects also gather internal WHATs (e.g., corporate technology aims or quality goals, and mandated safety or regulatory requirements). Internal needs would be shown in the WHATs section of the HOQ, but would be kept clearly separate from (and secondary to) the customer's WHATs.

Next, the team carefully consolidates the WHATs to combine duplicate items, pares their wording as far as possible without translating their meaning, and uses affinity grouping to order them. (*Affinity grouping* is a procedure in which related items are organized into categories by team consensus.) The WHATs are then entered on the HOQ.

After the team has consolidated the WHATs, it works with the customers to establish priorities for items in the list. At this time, teams may also evaluate other factors such as product-service data, customer-complaint data, and customer-based competitive assessment of similar products. These factors are indicators of customer priority (in addition to the explicit customer-priority ratings), and are often shown as supplementary columns of the HOQ.

The next step is to *establish the mechanisms* (the HOWs) *and their target values*. For this, the team generates a list of mechanisms that would satisfy the WHATs. These mechanisms are best expressed as technical characteristics or design requirements, instead of explicit solutions. The HOWs must be measurable in terms that have meaning to the customer. The team consolidates the HOWs using affinity grouping, similar to the consolidation of the WHATs.

The team next decides on a target value for each HOW, i.e., the HOW MUCH value for which the HOW should aim. The measurement must be quantifiable, and must be expressed in terms that are relevant to the customer. (For example, if the HOW was a report, the target value might be to issue it quarterly.)

Now, the team is ready to *establish relationships*. It discusses and determines the relationship of each WHAT to each HOW and assigns a strength value to each relationship. The strength values are typically *none*, *weak*, *medium*, and *strong* (which are often assigned numeric values of 0, 1, 3, and 9, respectively, to help highlight important relationships). These notations are entered symbolically on the house-of-quality matrix.

The team next *evaluates the HOWs*. First, it determines how difficult each HOW would be to implement. This assessment identifies the HOWs that will warrant special attention, if selected. The technical-difficulty rating is recorded as an additional row below the HOW MUCH area

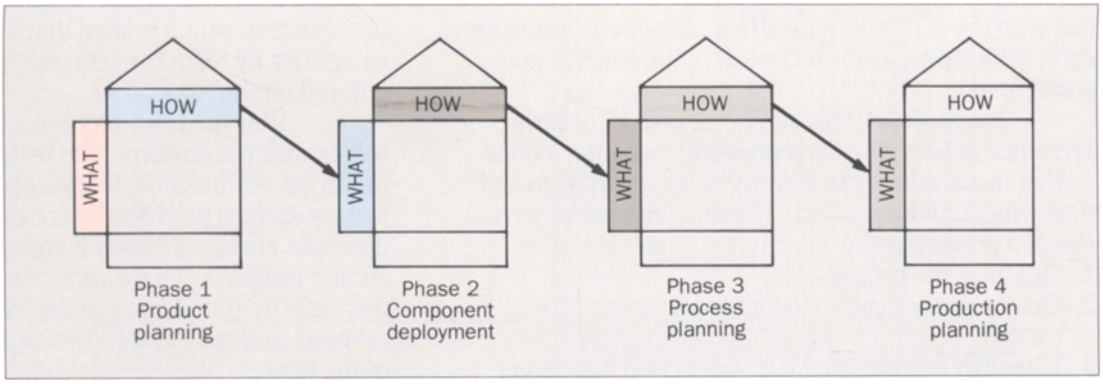


**Figure 4. A phased application of QFD matrices. Each level of matrix uses HOWs selected from the previous level as its WHATs.**

of the HOQ. (For the example in Figure 3, the team chose not to include this rating on their HOQ.)

Next, the team examines and assesses each HOW with respect to its interaction with other HOWs. The team assigns a *positive* correlation to the HOW if its implementation supports another HOW. A *negative* correlation means the HOW's implementation hinders another HOW. Each HOW's positive and negative correlations are now recorded in the "roof" of the house of quality. These correlations may be evaluated by inspection. Or, the QFD team may choose to assign numeric weights for the various correlation levels and then evaluate the correlations arithmetically.

This would also be an appropriate time to assess our competitors' abilities to achieve similar HOWs. If our company doesn't do as well at meeting a given design requirement, we'll need to pay closer attention to that requirement.

Not all the HOWs are selected for implementation. As part of this evaluation step, the team decides which ones will get done first. It calculates a technical-importance rating for each HOW (typically via QFD support software) based on the number of WHATs to which the HOW contributes, the strength of those contributions, and the customer-priority rating of those WHATs. This is the primary determinant of which HOWs are selected.

In keeping with QFD's focus on *important or new or difficult*, the team notes which of these HOWs deserve close attention because of their novelty or expected difficulty of realization.

The team is now ready to *analyze the HOQ and finalize the target values*. Standard criteria are available for diagnosing the sanity of the QFD matrix. Examples include:

- Empty rows (i.e., unfulfilled needs)
- Empty columns (i.e., unneeded mechanisms)
- HOW × HOW correlation (i.e., interaction of the mechanisms)
- Percentage of cells filled in the relationship matrix.

The team applies these criteria to decide if it should proceed (i.e., the matrix is sane) or should revisit prior steps (to clear up a sanity problem).

Finally, the team reaches a consensus that the target values of the selected HOWs are appropriate and are correctly scaled.

The six steps just described form the procedural flow for the highest level of QFD, which generates the house of quality. For organizations that are trying QFD for the first time, it's prudent to start with this basic process. As an organization gains experience with QFD, it can expand the scope of subsequent iterations on the same product or apply the process to other products.

What's most important is to integrate QFD into day-to-day business concerns; that is,

- Keep gathering the voice of the customer.
- Refer continually to the house-of-quality matrix as a guide for the enterprise.
- Link the target values with internal process-management metrics.
- Revisit the QFD process each time strategic decisions are considered.

Once the initial investment has been made, the ongoing use of QFD pays bountiful dividends.

**Refinements**

The QFD process is often depicted as being driven by a *sequence of matrices.* One popular strategy (which is favored by the American Supplier Institute, a leading QFD-consulting firm in the United States) is pictured in Figure 4.

In this strategy, each level of matrix uses the HOWs selected from the previous level as its WHATs in a phased approach. The four phases and their respective matrix constituents are:

1. *Product planning*, the phase discussed so far in this paper. In this phase, we are concerned with identifying technical requirements (as HOWs) that satisfy customer wants (as WHATs).
2. *Component deployment.* This phase identifies the component characteristics (as HOWs) needed to satisfy the technical requirements identified in Phase 1 (which are now treated as WHATs).
3. *Process planning.* This phase identifies the process characteristics (as HOWs) that lead to the component characteristics identified in Phase 2 (which are now treated as WHATs).
4. *Production planning.* Defines the production requirements (as HOWs) to achieve the process characteristics identified in Phase 3 (which are now treated as WHATs).

Another leading American QFD-consulting firm, GOAL/QPC, favors an approach that uses a *matrix of matrices.* The QFD team selects appropriate matrices from an arsenal of 30 different displays, as needed.[3] This allows the QFD team to consider analyses of customer wants versus product functions, functions versus cost, customer wants versus cost, technical characteristics versus functions, and many more.

These complex QFD approaches can interface tightly with the sophisticated quality-management systems seen in many Japanese corporations and a few American firms.[4]

**Applications of QFD**

QFD is a powerful, flexible approach that can be adapted to a wide variety of product-realization scenarios. Organizations that are interested in exploring the use of QFD will benefit from expert consultation, especially for initial applications (see Panel 2). The sample applications described in this section are typical.

The QFD approach is used as a tool for defining new products, as well as for diagnosing existing products. For a new product, the team starts with a nearly clean slate and can make sure that customer values drive all decisions about product characteristics, development methods, production processes, and support strategies for the product. When QFD is used to upgrade existing products, the team is more constrained by the processes already in place, but the same notions apply.

**QFD for a New Product.** A new software package is an example of a tangible new product that could be defined using QFD.

Here, the WHATs would be the criteria the *customer cares about* relative to the purpose the software would fulfill. These criteria might include tasks that need to be done, response time, availability, and so on. The HOWs would be mechanisms that fulfill these WHATs: attributes of architectural elements (e.g., modules) for a complex software system, or high-level design requirements (e.g., algorithms or data structures) for a more contained package. Target values would define associated parameters (e.g., coupling, response time, storage capacity).

For the more-complex new system, it would be appropriate to use the key HOWs as the WHATs in a

subsequent-phase HOQ to define their design attributes.

The phased approach could also be followed to ensure that appropriate development processes and resources would be in place, and that software production and support were adequate. For example, the design attributes might favor an implementation in an object-oriented programming language. The subsequent phases would then clearly specify language choice, programming environment, and developer training.

**QFD for a New Service.** Because the first trials of QFD were in the automobile industry, many of the case studies in QFD are drawn from automotive applications. This fact inhibits some people from considering QFD's use in service areas. When considering QFD, it's important to get beyond images of car doors and bolt torque and think in general terms of WHATs and HOWs.

Let's consider the case of a new service to be offered by a computer center—say, automatic data archiving.



Customer needs are still the WHATs and might include needs that concern data integrity, size of archivables, time to access data, etc. The HOWs would specify the characteristics of a service that would fulfill these customer needs; e.g., reliability and availability requirements, characteristics of documentation and training, and storage requirements.

Target values would establish measurable design goals that would satisfy customer expectations; e.g., mean time to failure, storage-error rate, readability of documents, and training time.

Subsequent HOQs for each of the HOW areas could define the mechanisms and processes needed to make them happen in a customer-satisfactory manner.

**QFD for an Existing Product.** In QFD projects that diagnose existing products, the WHATs are collected and processed just as though the product were new. However, the HOWs here are the existing realization mechanisms. Any target values extant are also entered on the house of quality.

The relationship matrix is filled in, and the HOQ is analyzed. Empty rows in the relationship matrix identify unmet customer expectations, while empty columns identify mechanisms that meet no customer need. Conflicts in the correlation matrix show that two mechanisms are acting in opposition.

The team then defines new mechanisms, as appropriate, and deletes mechanisms that are not related to customer satisfaction. Inappropriate target values are revised. As needed, the team reevaluates and respecifies the HOWs that only weakly fulfill important customer values or that interfere with other key HOWs.

Subsequent-phase HOQs can be generated to continue this realignment through all deployment phases.

**QFD for an Existing Service.** QFD is effective in diagnosing existing services as well as tangibles. As an example, consider a computer center's existing data-archiving service.

Once the HOQ has been populated, analysis might show that no mechanisms specifically address a need for data retrieval within five minutes. Or, it might show that the training of maintenance personnel wasn't taking place as soon as people were assigned to work with the archive-storage device. Or, it might show that the target value for maximum file size didn't jibe with the customer's needs (i.e., the voice of the customer). The team would redefine the HOWs (and their target values) to bring these mechanisms into alignment with customer expectations.

The QFD study could progress through further phases. For example, it could make sure that the training process is modified appropriately, that the specifications for the hardware and software elements are revised to deal with a 5-minute access time, and so on.

**QFD for Enterprise Planning.** Besides helping to define and plan products, QFD is superb for defining and planning the future of businesses. This application, called *enterprise planning*, follows the basic QFD paradigm in the same general way—that is, as though the business were a product.

Customer values are entered as WHATs, and the mechanisms that the business unit could use to implement these values are entered as HOWs. Of course, the process is working at a higher level, so the degree of detail will necessarily be coarser. That is, the HOWs and their respective target values can deal with such entities as business practices, development strategies, technology direction, or policy. However, the intent and execution are the same.

This application can be used for new or existing enterprises, for work groups or corporations, for a 2-year view or a 10-year term—it's all just a matter of scale.

**QFD for Process Management.** A related use of QFD is in defining and planning process-management activities.

Here, the WHATs could be internal-customer requirements from other processes, applicable expectations from external customers, and items carried down from a higher level, phased-QFD project. The familiar notions of HOWs and target values remain the same.

**QFD for Technology-Driven Engineering.** A final application of QFD is in the area of technology-driven engineering (as contrasted with the customer-driven engineering discussed so far).

In this type of work, the HOWs exist as attributes of a technology (say, a new optical-transmission medium). The challenge is to map these attributes to a set of WHATs in a way that will satisfy enough of a customer segment to be profitable for the enterprise.

As in most technology-driven exercises, this reverse processing is not likely to be efficient. If the WHATs collected for a known customer segment aren't fulfilled, another segment must be identified and its WHATs gathered. (Or, a new segment must be postulated, possibly a composite of existing subsegments.)

This reverse sequence is contrary to the spirit of QFD (and contemporary quality-management theory, in general). It's likely to be most effective with breakthrough technologies that promise to excite customers by solving heretofore unsolved problems.

**Looking Ahead**

QFD has been applied at AT&T in a variety of projects, including the definition of a lead-acid battery, a digital telephone-transmission system, and a telephone-network performance-analysis system. Also, QFD has been used for enterprise planning in software-technology deployment, for defining software tools, and for diagnosing development processes.

Typically, organizations that have used QFD once incorporate it as a key product-realization system. They cite such benefits as:

- Their understanding of customer needs has improved.
- More of the customer's critical needs were met.
- Their credibility with customers was enhanced.
- Unmet customer needs were discovered.
- Development start up is quicker because of improved communication.

Work that builds on this recent experience is currently under way at AT&T, including:

- AT&T's submarine system strategic-business unit is using QFD on several projects including new-technology planning, product definition, and internal-service definition.
- AT&T Network Systems has endorsed QFD as a preferred approach for new-product introduction, and is currently establishing pilot projects.
- At AT&T Bell Laboratories, the Computing Technology and Design Engineering Division is using QFD in its systems-engineering efforts to define computing-service offerings and enhancements.
- AT&T's Documentation Board is using QFD to develop a series of documentation-realization processes and customer-based documentation metrics.
- AT&T Network Systems is using QFD to reengineer its order-fulfillment process.
- At AT&T Bell Laboratories, the development organization for the R&D UNIX® operating system is applying elements of QFD to align its work plan with customer values. (UNIX is a registered trademark of UNIX

System Laboratories, Inc.)

As customer satisfaction, timeliness, and correctness become more and more crucial to success in the international marketplace, QFD will be more and more widely applied as the product-realization system of choice throughout AT&T.

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