

A TALE OF TWO QFDS

**Tammy North Comstock
University of Minnesota**

**Kevin Dooley (contact)
Arizona State University
PO Box 875906
Tempe AZ 85287-5906
Ph: 602-965-6833
Em: kevin.dooley@asu.edu**

CITE: Comstock, T., and K. Dooley (1998), "A Tale of Two QFDs", *Quality Management Journal*, 5(4): 32-45.

ABSTRACT

Quality Function Deployment (QFD) has become a widely used tool in the product development process. It helps design teams gather the wants and needs of the customer and organize and utilize this data so that a product which satisfies the customer will be developed. One of the reasons for the success and acceptance of QFD is that it is a very versatile tool. The traditional matrices and process can be modified in many different ways to fit the needs of the product team. Like any innovation, however, QFD in practice has been implemented with varying degrees of success. This paper will examine two QFD projects, one commercial and one defense, in order to identify the factors that favor successful implementation. It will be posited that successful QFD requires both implementation effectiveness as well as the strategic accuracy of adoption--firms need to adopt QFD for the right reasons, and effectively implement it once the choice has been made.

INTRODUCTION

Quality Function Deployment (QFD) is a method that uses matrices to show the relationship between two or more sets of concepts. QFD directly facilitates a customer-focused product and process design by making explicit the relationship between design characteristics and customer requirements. The QFD concept was first proposed in Japan as a way to stress the importance of quality control in the planning stages before a product goes into production (Hauser and Clausing, 1988). Since the late 1980's, QFD has become widespread throughout many industries, including automotive, electronics, and defense (Cohen, 1995).

A "full" QFD consists of four phases: product planning, design deployment, manufacturing process planning, and production planning (Hauser and Clausing, 1988). During the construction of the Phase I matrix, the relationship between customer requirements and the product design concept are examined to determine which product features are most crucial. In Phase II matrix, individual part characteristics are compared to design features; in Phase III, process plans are compared to part characteristics; and in Phase IV, operational plans are coordinated with process plans.

The *voice of the customer* is often referred to as the "cornerstone" of the QFD process as it drives the rest of the subsequent value analyses. For this reason, many users extend the method through use of a customer information table or pre-planning matrix, as a way to organize and screen important customer information before proceeding to the first phase matrix (Pugh, 1991). Other extensions include subsystem QFDs (e.g. Enhanced Quality Function Deployment (Clausing, 1994)) and concept selection tables (Pugh, 1991).

While the methods of QFD itself have been fairly well developed and tested in industry, very little research has addressed the actual implementation of QFD, especially across different types of industries. The purpose of this paper is to examine the implementation of QFD via two projects done at separate companies. One project involved a very complicated defense weapons system while the other involved a new design for a piece of fitness equipment. While the products were quite different, but both teams faced some of the same issues and experienced some of the same problems during the QFD process. The two projects are summarized in Table 1. First, a summary of existing research concerning QFD success factors will be presented. Second, the two QFD cases will be discussed. Finally, differences and commonalities between the two projects will be highlighted. Note that actual QFD-matrix data cannot be shown here for proprietary reasons.

--insert Table 1--

We shall propose that successful implementation of QFD depends on both implementation effectiveness and the strategic accuracy of the QFD adoption. One needs to both manage the QFD process, as well as adopt it for the correct strategic reasons. Relative failure can occur through either poor implementation or poor strategic choice.

QFD SUCCESS FACTORS

QFD is a very versatile tool that can be used in numerous ways and offer benefit to the design effort. QFD has yet to see extensive usage however. Jayaram et al. (1997), in a study of quality tool usage, found that QFD was one of the least used quality tools. Its effect appears positive however. Vonderembse et al. (1997) performed a descriptive study of these issues. Their sample of 40 firms and 80 projects indicated that QFD helped improve product design, design documentation, and customer satisfaction, while it had little impact on cost or time-to-market. They claim that increased training and experience will provide the greatest leverage to QFD success.

Failure is not uncommon however. QFD is a tool, and like any other tool, its uses are limited. Even though the QFD matrices can be altered and tailored to fit a wide variety of projects, not every design will require the rigors of the QFD process, and not every project team will find it worth the time and effort required. Sometimes, however, even if a project is an appropriate application for QFD, the QFD effort may fail. Cohen (1995) prescribes the following factors for successful QFD implementation: organizational support, explicit objectives, appropriate team, and project management.

Pandey and Clausing (1991) surveyed over 200 individuals who had participated in one capacity or another in at least one QFD project. Although a majority of the respondents had participated in fewer than five QFD projects, over 60 had been involved with five to ten QFDs and many had experience with over ten QFD projects. The survey used two measures to determine the level of success obtained by QFD: perceived level of benefit to the project due to the use of QFD, and perceived rate at which QFD applications were increasing within the respondent's organization.

One key finding from the survey was that the top and middle management in an organization play a big role in whether or not QFD projects will succeed. Over 95% of the respondents that reported that QFD was becoming more widely used and accepted within their organizations believed that top and middle management were supportive of their QFD efforts. Meanwhile, slightly higher than 50% of the respondents who did not believe that QFD was spreading perceived that middle management was not supportive. The importance of middle managers appears to derive from their role as project managers; the importance of top management appears to derive from their role as innovation diffusers.

Another success factor was the degree to which a QFD team is enabled to alter or customize the QFD process. Often the relationship between what is assumed by the "ideal" methodology and what is actually present (for example, with respect to ambiguity and completeness of information) is weak at best, and customization is necessary. Customization may also simply occur due to time constraints. Their study showed that 83% of the respondents reported making changes to the traditional approach, and that 95% of these respondents found the changes to be helpful. The relationship between altering the process and QFD success showed that of those respondents who felt that QFD did not benefit the project, none of them had made many changes to the traditional QFD approach (half said that no changes had been made). Another interesting finding was that groups that customized the QFD matrices tended to feel a greater degree of ownership of the process and the methodology than those groups that utilized the process without making any alterations.

The final factor that was highlighted by the study was the composition of the QFD team. Cross-functional teams are usually considered necessary for QFD success; such functional representation should go beyond design and manufacturing, and may include marketing, sales, legal, human resources, purchasing and supplier management--and even suppliers and customers. It was found that the completeness of the QFD team was very strongly related to both the perceived degree of benefit derived from the QFD and the rate at which the use of QFD was growing within an organization.

In summary, factors such as management commitment, project management, and customization point towards the importance of successful implementation. Conversely, a factor such as the use of a cross-functional team may have more to do with strategic choice than implementation per se. QFD is more likely to succeed if it's applied in a situation requiring cross-functional representation. Thus, QFD success depends on both content and context.

COMMERCIAL PROJECT

The first case study involves a commercial firm that specializes in fitness equipment. The company involved was interested in developing a machine based on the concept behind a very popular line of health club machines but at a price which a consumer could afford for a piece of home-use equipment. Marketing research by the firm indicated that the club versions of the machines were very popular, yet no one had developed one that the "average" consumer could afford. The company's senior leaders felt that if a new product could be developed quickly and designed right, the company would be naturally associated with what they felt would be the next big push or fad in the fitness industry. This name recognition and association would be a key to sales later on after other firms began bringing similar and perhaps less expensive designs to the market.

Management felt that the key to this project would be to develop a design that the public would like and to get it to market early so that the company would be associated with leading the field for this type of machine. The product manager for the project had very little experience with QFD, but he had heard of the method through various seminars and pitches from local research firms. He presented the idea of utilizing QFD to upper management and received approval for funds to support such an effort.

The QFD Process--Gathering The Information

Since the company had very little experience with QFD, the product manager decided that the best approach was to hire the services of an outside firm that specialized in market research. For a fee, the firm would conduct market research, compile the wants and needs of the customer as obtained from the research, and set up the initial "house of quality" (Phase I matrix).

The outside firm started their research by compiling four groups of approximately 10 to 14 people each for focus group sessions. The focus group sessions lasted approximately three hours each and were held on four consecutive nights in one week. The format for each session was the

same. The participants met in a hotel conference room in the evening, knowing only that they would be asked their opinions on some topic dealing with exercise. The participants did not know what company was funding the research, and each participant was paid for their time.

The moderator of the focus group asked general questions concerning each person's level of activity and general views on fitness, and about what types of fitness equipment each participant owned or had considered purchasing in the last year. Next, a working prototype of the newly designed product was shown to the participants. The fitness firm had made the prototype in their own model shop based on preliminary design ideas, but the prototype was not visually correct. Each participant was allowed to get on the machine and try it out for about thirty seconds to a minute. This allowed them to get a feel for the exercise in general and have enough knowledge to form an opinion about the prototype.

The moderator then asked them to list 15 facets, or areas of concern for the product, and to distinguish between "This product must..." and "I wish this product would...". For example, for the facet "appearance", some typical responses for the "This product must" list were that the product must look nice enough to keep in the living room, it must look sturdy and not intimidating, and that it must not appear too big. For the "I wish this product would" category participants listed that they wished the product would blend into their home environment, have a natural wood construction, and come in several different color options.

Other facets or areas that were covered involved such things as pricing, computers and electronics, optional equipment, customer service, warranty issues, and motivation to use the equipment. The moderator would ask for clarification if he did not understand a particular want or wish. A scribe generated a computer listing of the requirements. Each participant was asked to rate the importance of each requirement using a five point Likert scale. The group was allowed to discuss the items on the list, but ratings were done secretly. At the end of the session the moderator prompted for open feedback, especially concerning price sensitivity.

After this research was completed, the outside firm compiled a master list which showed all of the customer requirements from the four groups combined; they combined requirements where they thought appropriate, in order to reduce the size of the list. The importance rating for a requirement was simply the average rating from all respondents.

Analyzing the Data

Presentation and appearance are often the most important deciding factors when it comes to liking or not liking a product. The font used on a product label or the words that a salesman uses to describe a feature can often make or break a sale even though the label and description have

little if anything to do with the function of the product itself. If a business report is bound professionally and contains full color glossy pictures and intricate graphs, then people may give it more credibility than it is due. This same type of scenario may have occurred with the fitness company when they were presented with the QFD material.

After the focus groups were completed, it took the research firm approximately four days to compile all of the information and put together the house of quality matrix. They then arranged an all day meeting with of the product manager and representatives from design and marketing to present what they had put together and to walk them through the completion of the relationship matrix. At first glance, it appeared to be rather impressive work. The house of quality contained 40 customer requirements with subsequent ratings. The group worked the entire day to complete the relationship matrix.

The problem appeared to be that everyone was so impressed with the presentation of the information that no one really looked at what kind of information was being presented. When several customer requirements were combined into a single more general requirement in order reduce complexity, the team ended up with very general requirements such as “Must be adjustable” or “Motion must be comfortable” which the team had known in the first place. In order to find out the details behind these requirements, they would have to dig into the report given to the program manager that showed all of the customer input. There were several requirements placed in the matrix that were novel to the design team, such as “Tension should adjust in increments that are numbered” or “Should have incentive features to encourage working out” which the team may not have considered on their own to be very important. However, much of the really good information was left buried in the product manager’s report.

The biggest problem, however, was with the engineering characteristics or HOWs. These are supposed to be the translation of the customer requirements into measures that the engineers could gauge the design against. Unfortunately, the engineers were not consulted on the formation of these measures; instead, the research firm came up with their own, and the results were not that impressive. This confirms research by Griffin and Hauser (1993) that shows that customer requirements should be categorized by both the design team and the customers (not by an outside group), and that the design team should develop engineering characteristics.

One of the advantages of having a good engineering characteristic is that it allows the design team to test sections of the design as they go along to see if the particular component or subsystem meets the needs of the customer. This eliminates situations in which an entire unit must be built and tested in order to get feedback on the progress of the design. This early or progressive testing would not be possible with a large number of the measures developed by the research firm,

however, because the measures were based on a jury system which would require an entire unit in order to get feedback. For instance, if the customer requirement was “Unit must be comfortable to use”, the corresponding engineering characteristic was “Number of positive comments regarding comfort of use”. This type of measure required a jury of people to actually get on the unit and try it and give their opinions. The fast development times for this project, however, did not allow for the iterative process of building prototypes and obtaining feedback. The team needed a design direction that they could go with and test in the labs as they went. They needed to know, for instance, that a customer needs the handgrip to be covered with a particular durometer of foam and be located from X to Y inches above the pivot point at their hip. Instead they were basically given the watered down customer wants in a re-worded format.

Also, some of the engineering characteristics that were developed were just not measurable. How could one determine the “Number of ways the electronics could be soiled by perspiration” (in response to the want that the electronics be protected from perspiration) or the “Number of injuries occurring during assembly” in response to the customer want that the unit be safe and easy to assemble? Not only would these be difficult to measure, but what company would allow their customer to assemble a unit if they were expecting injuries?

It appeared that the research firm had taken the “easy way out” on developing these measures. If the company had been allowed to be involved in the development of them, there may have been much better results. For instance, one of the customer wants was “Must not be hard on knees and joints”. The company had a physiologist on staff with experience in setting up studies to measure joint stress and impacts on specific parts of the body during exercise. If she had been consulted, she could have made several suggestions for engineering characteristics that would have involved lab testing of components or very rough working prototypes. Instead, the engineering characteristic identified by the research firm was “Number of knee/joint injuries in sample group”.

Even though the company measures were not the best and proved to be a stumbling block in the QFD process, the information from the focus groups was used to some extent by the product team. The product manager brought the completed matrix to the team meetings and briefly explained the QFD process to the members. He then told them that the design must satisfy the customer, and thus this document (the house of quality) would be a very important reference for them. If they were considering design options or owner’s manual wording or anything else which affected the design, then they should have the wants and needs of the customer in mind. The matrix was discussed for a short period of time, and the team members seemed to like the concept. In fact, all said that they wanted a copy of the matrix so that they could refer to it when needed.

The design engineer did use some of the customer data when looking at possible features that could be included. For example, an arm motion independent of the leg motion came up as an important requirement, so this became one of the focuses of the engineer. The electronics group also used some of the information to determine features of the electronics. For instance, one of the higher rated customer requirements dealt with the idea of giving the user feedback on how their fitness program was progressing. For this reason, the electronics for the unit was designed so that a fitness test could be performed by the user that would give them a score based on their heart rate after a particular time interval on the machine. By taking the fit test periodically over a period of weeks or months, the user could gage their progress by comparing their scores. This could work as a motivational tool for people who need that type of feedback to keep exercising.

Lessons Learned

Although the data gathered in the focus groups was useful to the team, the information could have been utilized to a much greater extent had the organization of the data and the translation of the data in the matrix been better. Several things could have been done to make this a more successful QFD project. One aspect to consider was whether or not the right people were involved in the QFD process. When the meeting was held to discuss the engineering characteristics and complete the relationship matrix, there were representatives from product management, marketing, and design. There was no representation from quality (someone who understood the QFD process and had been involved with it before), physiology, industrial design, or electronics present at the meeting. If a team consisting of broader representation had developed the engineering characteristics, the characteristics may have turned out to be more useable and measurable.

Another improvement would have been to customize the matrix or the process to better meet the needs of this team. In this case, one of the problems encountered was the “dilution” of the customer requirements due to combining several requirements into more generic categories that encompassed a broader area of concern. While necessary to reduce problem complexity, a great deal of valuable information was being hidden. For instance, precise information on what customers wanted for adjustment features was lost in a category known as “Unit must be adjustable”. Only by looking through the product manager’s report could one see that the customers were concerned with specific height adjustments, stride length variation, hand and arm movement adjustments, and elevation adjustment capabilities.

One way to deal with this “dilution” issue might have been to break the matrix into smaller matrices for specific areas of concern. For example, approximately 20 percent of the customer

requirement data related to electronics, yet the electronics were basically developed as a separate unit from the machine itself and simply had to fit into the console of the completed unit and be compatible with the rest of the machine for things such as sensors, connectors, and wire routings. The separation of the electronics customer data would have made for a “cleaner” and less cumbersome matrix while leaving more room for consideration of more specific customer wants.

A pre-planning matrix would have also benefitted implementation. In this case, the pre-planning matrix may have helped deal with such wants as “Should be of natural wood construction” or “Must come in several different color options”. These were very important considerations since the appearance of the product could make or break a sale, but these styling considerations could have been dealt with in another forum rather than the house of quality. It may have been better to take items such as these out of the matrix and just put them in front of the team to consider. For example, the team may have decided that there was no way that the unit could be made of natural wood (due to the bends and linkages required in the design) so that the only options would be to not make the unit from wood (disregard the want) or to use wood veneers to give it a wood appearance. This styling question was actually dealt with easily by the team when it considered the design and styling options.

The requirement of several color options was one that could not be as easily decided upon by the team, but it was also a requirement that did not dramatically impact the remainder of the mechanical design. The mechanical designers did not care what color the metal parts were painted, and the electronics group didn’t care what color the computer buttons would have to be in order to match the color scheme as long as a decision one way or the other was made. Therefore, this requirement could have been taken from the main matrix and a decision made in a different forum.

The actual use of the data was another area that could have been improved. For example, during one team meeting an industrial design firm was presenting their proposals for the overall look of the product. One of the designs had a two-bar support for the base that made the unit look stable since it did not appear that the machine could tip over. The design was almost immediately rejected because an I-type frame with a single support bar would provide adequate stability while the extra bar would only add cost and weight to the product. This may have been a good decision, but the team should have consulted the QFD matrix that showed that sturdiness was one of the top customer concerns. The engineers may have known that the single-bar base would provide a stable platform, but would a consumer looking at the product for the first time know this? Would the customer have perceived more stability with a two-bar base? The extra cost of the two-bar base may have been warranted if the customer’s perception of the machine had been improved a great

deal. This was just one instance when the QFD information may have helped the team make a good decision.

Overall, the QFD process was helpful. The team gathered valuable customer information, and some of it was used by engineering to design the product and by marketing to focus on the selling points that would appeal to the customer. Any time the team makes an effort to learn the wants and needs of the customer, the product will ultimately benefit. In this case, however, the information that was gathered could have been used and organized in a much more effective manner.

DEFENSE PROJECT

Background

Often when a rather complicated and highly technical project is starting off, the team can feel overwhelmed by all of the information that is in front of them and the decisions that will have to be made. Every member of the team is more than likely trying to jump ahead to visualize the end product which will eventually be designed and manufactured, yet each knows that the design process will involve numerous steps and iterations with several changes along the way. One advantage which QFD can offer to a project involving a complex design is that it offers a structured and formal way to approach and organize the technical data and customer information which can often slow a team down if it is examined all at once. The QFD process not only gathers and organizes the voice of the customer, but it can also be used to focus the efforts and limited resources of a team on the aspects of the design, which require the most attention.

A project team at a defense contractor was working on the design for a weapon system. The design for the new system was to be close to one that the company was already manufacturing, but this new system was to be “smarter”. The new design would be fitted with improved electronics for guidance and upgraded hardware for better control.

With the extreme conditions that this end product would see, the complexity of the navigation system, and the obvious need for any possibility of error to be eliminated for risk of disaster, this project would be very complicated. After years of research and initial design work were completed and the concept proved feasible, it was time to commit further by actually building and testing some limited function prototypes. At this point there were other defense contractors in the running to design and build the product, and the next step was to downselect to a smaller number of contractors by examining cost data and performance test results.

The main goal of the project team at this time was to come up with a more formalized design package which would be close to the design of the final product as far as features,

performance, and cost were concerned. This involved adding or eliminating possible features for cost or performance reasons and diving into the details of the actual design. This was a challenge to the team not only because of the pressures associated with the competitive downselect process, but because of the nature of the defense industry at the time, the resources available to the team (including money, computer modeling time, and manpower) were limited. The manager of the project had heard of QFD through some of the classes offered internally at the company and through other QFD applications that had taken place at the company, and he thought that this might be a good application. It took only a few conversations with upper management to get the approval to try using QFD.

The QFD Process--Organizing the Data

In order to kick off the QFD process, the project team was given a day-long introduction to QFD and a quick overview of some of the past uses of it in the company. The overall concept of QFD was well received by the group, but they were unsure if they had the time or the need for all four phases. Since a large portion of the product had already been basically defined, the team decided that they wanted to use QFD more to focus their resources on the “important” aspects of the design rather than try to “develop” the design from a clean slate using the traditional four phase approach. In addition, due to the complexity of the design and its division into systems and subsystems, the team felt that they would need to modify the traditional QFD matrices to better suit their needs.

The team discussed several options for modifying the matrices that would make the process efficient and yet beneficial. One of the first approaches they considered was to construct a “traditional” Phase I matrix with the customer wants and technical requirements along the left side and engineering characteristics along the top. The group at first thought that they could stop after this first phase since they would know what engineering requirements to test to based upon the engineering characteristics which would be derived and placed along the top of the matrix. After some discussion, however, the team decided that there were too many technical requirements and too many minute details to be handled in the matrix. Besides, the team felt that they had a pretty good feel for the engineering characteristics and performance criteria which would have to be met due to all of the documentation which spelled out the government’s requirements for the dispenser. The Request for Proposal (RFP) and Statement of Work (SOW) gave detail after detail of what the unit was to do functionally, so the team felt that the idea of generating engineering characteristics in a Phase I matrix was not worth their efforts at the time. The team also considered breaking up the design into several major subsystems and performing a QFD on each of the subsystems.

However, the team felt that not only would this take too much time, but also they were worried that some relationships that existed between subsystems might be ignored.

The idea that the team finally decided upon was a combination of the previous two ideas. They decided to place customer requirements (obtained from government documentation) along the left side of the matrix; importance ratings were obtained by surveying government officials and other people who were or had been associated with similar types of programs. They placed actual subsystems along the top of the matrix. For example, customer requirements such as “Operates in an area ranging in size from AxB to CxD”, or “Functions in temperature range of G to H degrees” were placed along the left side; while items such as “Part A of the navigation system” and “Element B of the navigation system” were placed along the top. The team’s main goal with this matrix was to examine which elements had the greatest effect on meeting the wants of the customer on the left side of the matrix. It was on these elements that the team would focus most of its efforts and limited resources.

The team followed through with their plan and constructed a matrix with the customer/technical requirements along the left and subsystems and specific pieceparts along the top; the group was then asked to evaluate the strengths of the relationships between the pieceparts and the customer requirements. Would varying the design or function of this part have a strong, moderate, weak, or no effect on this customer want/technical requirement? Of course, the team realized that if they were to do something “drastic” to the piecepart in question then it would affect every customer requirement. For example, if they eliminated a component entirely, then the entire mechanism would fail to function and would thus affect every other requirement. For this reason, the group agreed that they would only consider design changes and functions within a “realm of feasibility for the project”. This meant that only realistic piecepart designs and functions could be considered when determining the strengths of the relationships.

Analyzing the Data

After the relationships had been determined, the scoring was done so that each piecepart or subsystem could be given a relative importance score. The team examined the ratings and looked at which pieceparts had high scores since this could indicate that the part should receive more attention and focus from the team. This process gave the team more direction for their efforts, and although there were no big surprises to be found in the importance ratings, the completion of the relationship matrix turned out to be the most crucial aspect of the entire QFD process for this project.

The real benefit from the use of QFD was that the right people were brought together early in the project to discuss some very important aspects of the design. During team meetings representatives from aerospace engineering, electrical and mechanical engineering, project management, and manufacturing engineering were present to discuss the effects on the final product performance of altering the design of the various components listed along the top of the matrix. The discussions concerning what would happen if Component A was changed or Component B was made from a different material seemed very basic at first, but then a machinist would bring up the fact that changing Component A would greatly increase tooling costs while aerospace would voice their concerns over not changing Component B due to weight or space limitations. In a large number of instances the changing of one component would impact the performance of another, and in many of these cases, this information might not have been discovered this early if the QFD process had not been used. The aerospace and mechanical engineers may have continued on the development of a subsystem not realizing that the electrical engineers' jobs could be made much easier if only this or that were done.

Some heated debates and arguments actually broke out during the two sessions it took to complete the relationship matrix, as there were many opinionated people who wanted to discuss their point of view about how to get the best final product. In the end, however, a majority of the team agreed that some very valuable information was exchanged between the various functional groups working on the project.

Another benefit arising from this project was that it allowed the team to better understand the technical requirements for the product. The language involved and simply the amount of information presented in a technical data package (TDP) which spelled out the technical requirements for the complicated system was overwhelming. The QFD process forced some of the members of the team to carefully go through all of that data to figure out what the customer actually wanted. If a requirement was unclear, the person going through the data was not able to summarize it into a concise statement (as it would be placed in the matrix) and thus the team would have to discuss what they thought it meant or they would have to go to the customer for clarification. This brought about interesting situations where members of the team would disagree about what a requirement was actually asking for in the TDP, which was pretty surprising considering that the TDP was supposed to be a clear-cut engineering document.

Another benefit of the process of gathering and clarifying the customer wants was when the customer was asked about a particular requirement. The team was concerned about the requirement and the unit's ability to meet it under extreme environmental conditions. After discussion with the customer, it was discovered that they were not concerned about subjecting these

initial units to extreme conditions at that time. Thus this would not have to be a concern for the team. The defense contractor would probably have found out this information eventually during the development process, but they saved some time and effort by discovering this up front.

Lessons Learned

A great deal of information was exchanged and many requirements were clarified during the QFD process for this project. People from several different areas of the company came together in one meeting room to discuss the relationships between various aspects and components of the design and the effect that each of these had on producing a product that would satisfy the customer. There were numerous things that contributed to the “success” of this project. One was the management support (both middle and upper) which was given to the team during the initial phases of the project.

It was the project manager who first proposed the idea of using QFD; he had to gather information on not only the QFD process, but on other QFD projects which had been undertaken at the company and their results. He then had to sell the idea to upper management in order to obtain permission and funding for the team. This was no small task in a defense environment where the employees charged to contracts based on the half-hour. This meant that every time a person spent any recordable time (twenty minutes or more) working on the QFD process, this time would have to be charged back to the contract and the money (based upon the salary grade of the employee) deducted from the budget of the project.

The QFD process can be especially taxing on a time charging system like this due to the number of people that must attend meetings and the length of time these meetings can take. For this project, there were two meetings held (each lasting approximately four hours) with a minimum of eight to ten people at each meeting just to complete the relationship matrix. In addition there were many hours of preparatory work done including sorting through the TDP to gather the customer wants, discussing and clarifying these wants, typing up the matrices, training the team in the QFD process, and other miscellaneous tasks like making viewgraphs for the team meeting presentations. Without management support, a QFD project would have a very difficult time surviving in a defense environment based solely upon the hours charged to the contract.

Another thing that helped this team along in utilizing the QFD process was that the team had been exposed to other quality tools training. Shortly after the team was selected to work on this contract, a majority of the team members went through approximately three days of training. This training included some team building exercises as well as a brief introduction to the concepts

of design for manufacturing (DFM) and design for assembly (DFA). In addition, later on in the contract, a consultant came in and walked the team through a DFM/DFA exercise on the product. The team was quite successful in this endeavor in that they significantly reduced the part count for the product (a majority of this came from the elimination of fasteners by redesigning parts) and made it a much simpler product to manufacture. This DFM/DFA training and experience helped put the team in the right mindset when it came to the QFD. Since the team was now accustomed to the idea of planning ahead for quality in the product they were able to avoid the “We’ll deal with that when the time comes” approach to product development.

Although the team did experience success in some aspects of the project, it was clear that some things could have gone much better. The team primarily used QFD as a tool to focus their development efforts and to a degree they did succeed. The team gained a greater understanding of which components or subsystems had the greatest effect on meeting the customer’s specifications, and they were able to emphasize these areas in their development tasks and research. The team also exchanged information within the group in a much more timely fashion than would have occurred without the QFD process.

However, there were some problems encountered along the way that took something away from the experience. One of these was that the personalities of some of the team members got in the way during the QFD meetings. While completing the relationship matrix, there were times when the discussions about component interactions and the effect on the customer requirements of altering a component escalated. The idea of what was best for the design was ignored as people became territorial about tradeoffs. A great deal of this problem may have been due to the number of managers who were present in the meeting. These managers were especially emotionally involved in the QFD process as they felt that they had to look out not only for the project’s success but for the decisions that their team were making or having made for them during the QFD and design process. It may have helped in this case to further limit the number of people who were involved in the completion of the relationship matrix, but this would have been at the cost of losing some very valuable information exchange among all groups and all levels of employees within the groups.

One concern that some of the team members had when the QFD project was complete was that they did not feel that they had obtained enough benefit from the process to justify the time and effort which went into it. Although they felt that the QFD had been somewhat helpful in prioritizing the resources of the team, they did not feel that it did much for helping to actually design the product. The team chose to place main components or subsystems along the top of the matrix in order to keep the size of the matrix manageable and because they felt that they had most

of the design complete. This simplification, however, took something away from the QFD process since the level of detail covered was limited.

The idea of placing components at the top of the matrix rather than engineering characteristics may have seemed like a good way to prioritize the team's responsibilities, but the absolute importance ratings which the team used for prioritization did not really show anything that the team didn't already know. They knew that Subsystem D was very critical to the design and that Item F only really affected Customer Wants 3 and 7, so when the matrix was complete and the ratings were tallied, some members of the team had a "No kidding, we already knew that" attitude that may have been at least partially justified.

The team began the QFD project with a top-level design, and they had an idea about which subsystems were the most crucial and which ones would require the most effort in order to come up with a detailed design. For this reason, it may have been more helpful for the team to pick Subsystem D or a few other subsystems that they were concerned about and focus on them by constructing individual QFD matrices. If this had been done for a select number of major subsystems or components, then the designers would have been able to get into the details of the design and the very important effects that these details would have had on the overall success of the product. This would have kept the matrices to a manageable size and yet allowed the designers to get their hands on the details that they needed. Naturally, this approach would not have allowed the entire design to be discussed as the approach that was used did, but it may have been more helpful to the team.

CONCLUSION

The two case studies examined were driven by very different business objectives. The commercial firm was concerned with time to market and features that capture market attention. They needed to get the design out the door quickly before the competition developed a similar product, and they were dealing with some gray areas when it came to customer satisfiers. What is a comfortable stride? How does one decide if a unit looks too heavy or not sturdy enough?

The defense firm, on the other hand, was concerned more about the technical details of the design and the ability of the design to meet very specific customer wants. Unlike the commercial company, the defense firm knew what the customer was demanding from a performance standpoint--it was spelled out for them in the documentation package. Their concern was in their capability to address all of these requirements in a complex design with many interactions between subsystems and pieceparts. They needed a way to keep all of their information organized and the team focused on the aspects of the design which were most important to satisfying the customer.

Our findings, as well as other findings documented in the literature, lead us to propose the following model of QFD effectiveness (see Figure 1). The model is partially adopted and adapted from an innovation implementation model presented by Klein and Sorra (1996).

--insert Figure 1--

Simply put, QFD effectiveness depends on the effectiveness of QFD implementation. This relationship is moderated, however, by the strategic accuracy of QFD adoption. QFD effectiveness refers to the benefits accrued from implementation (better concept designs, increased voice of the customer, etc.). QFD implementation effectiveness refers to the consistency and quality of targeted use of QFD. Strategic accuracy of QFD adoption refers to the fit between the needs that drove adoption versus the capabilities of the methodology.

There are two distinct ways in which QFD could be ineffective. First, it could suffer from *poor implementation*. This would be the case where QFD was adopted for the right reasons, and it was used in the right place at the right time, but it was not effective because it was implemented in a haphazard and/or improper fashion. Second, it could suffer from *poor strategic choice*. This would be the case where the tool was applied in robust and correct fashion, but where there was very little value added because the reasons why it was used were not strategically compelling. Let's expand on these two barriers to effectiveness in terms of some general propositions that follow from the case studies.

QFD Implementation Effectiveness

1. *QFD is more effective when the right people implement it.*

The commercial firm made the mistake of having the consultants overly involved in collecting data and composing the house of quality. The team was relatively small and only had marginal cross-functional membership. The defense firm had a team representing a broad cross-section of the relevant functional areas, and engineers were directly involved with composition of the matrices. This is in support of Griffin and Hauser's findings (1993).

2. *QFD is more effective if the two sets of data can be characterized by truly complex interactions.*

The matrix for the commercial product compared customer requirements versus measures of customer satisfaction rather than engineering design characteristics. The subsequent correlation analysis was trivial because the matrix only contained elements on the main diagonal--there was a one-to-one correspondence between each requirement and each measure. Conversely, the matrices for the defense project were useful because they clearly illustrated the complex interrelationships between requirements and subsystem components.

3. *QFD is more effective if applied at a level of detail that enables "hard decisions".*

In the commercial product, when product attributes were combined into higher level categories, they became trivial. In the defense product, submatrices were considered to enhance detail, but were decided against because of time constraints. In both cases, the QFD method had little or no impact on the act of detailed design because it was carried out at too abstract a level.

4. *QFD is more effective if managed in such a way that it enabled effective group processes to take place.*

In the defense product, the larger team size caused functional groups to become territorial, leading to less-than-optimal group process.

Strategic Accuracy of QFD Adoption

5. *QFD is more effective if it's adopted for particular needs.*

The commercial firm adopted QFD primarily as an experiment; there was no clear understanding of what it might help the firm do better. The defense firm was clearer on why they were using it, and was anxious to customize it to fit their needs.

6. *QFD is more effective if the purpose of QFD-usage is clear.*

The commercial firm lacked knowledge of why QFD was useful; it therefore made the mistake of examining customer satisfaction measures rather than engineering design characteristics in the house of quality. The defense firm knew they wanted to use QFD for doing value engineering.

7. *QFD is more effective if it's applied in an appropriate context.*

The commercial firm was developing a new product platform and was using QFD in the early stages of conceptual design--an excellent context and time to use QFD. The defense firm was developing an incremental (derivative) design from an existing product, and was using QFD after a concept was already in place--this context is not as ideal. QFD is probably best suited for complex problem solving involving multiple functions, at the beginning of the conceptual design phase.

In summary, the commercial firm appeared to have done adopted QFD for the appropriate strategic reasons, but was not fully aware of this; they were not terribly effective in implementation. Nevertheless, because the context was correct, some positive learning occurred. The defense firm appeared to have successfully implemented QFD, and knew why they were doing so, but their adoption was perhaps not as strategically critical. For this reason it appears that they benefitted more from the "process" of implementation (e.g. verifying requirements with the government customers) rather than the end result of the implementation (the QFD matrices).

In summary, the following questions should be addressed by managers considering adoption of QFD:

- Why are we adopting QFD?
- What steps will our QFD consist of?
- Is this the best time and place to use QFD?
- How do we successfully implement QFD?
- Who should implement QFD?

ACKNOWLEDGEMENTS:

The authors wish to thank the anonymous reviewers, copy editor Jane Crouse, and editor Barbara Flynn for their helpful suggestions.

REFERENCES:

- Clausing, D. (1994). *Total Quality Development*. NY: ASME Press.
- Cohen, L. (1995). *Quality Function Deployment--How to Make QFD Work for You*, Reading, Mass.: Addison-Wesley Publishing Company.
- Griffin, A., & Hauser, J. (1992). "Patterns of Communication among Marketing, Engineering, and Manufacturing: A Comparison Between Two New Product Teams," *Management Science* 38(3), 360-373.
- Griffin, A., & Hauser, J. (1993). "The Voice of the Customer," *Marketing Science*, 12(1): 1-27.

- Hauser, J., & Clausing, D. (1988). "The House of Quality," *Harvard Business Review*, 66(3): 63-73.
- Jayaram, J., Handfield, R., and S. Ghosh (1997), "The Application of Quality Tools in Achieving Quality Attributes and Strategies," *Quality Management Journal*, 5(1): 75-100.
- Klein, K., & Sorra, J. (1996). "The Challenge of Innovation Implementation," *Academy of Management Review*, 21(4): 1055-1080.
- Pandey, A. & Clausing, D. (1991). "QFD Implementation Survey Report," Laboratory for Manufacturing and Productivity, Massachusetts Institute of Technology.
- Pugh, S. (1991). *Total Design*, Wokingham: Addison-Wesley.
- Vonderembse, M., Van Fossen, T., & Raghunathan, T. (1997). "Is QFD Good for Product Development? Forty Companies Say Yes," *Quality Management Journal*, 4(3): 65-79.

Table 1 The Two QFD Implementation Cases

	Commercial	Defense
<i>Product Type</i>	New platform product	Derivative of existing product
<i>Team</i>	Small, limited cross-functional scope	Large, broad cross-functional scope
<i>Timing</i>	Early in conceptual design phase	Early in detailed design phase
<i>Prior Training/Experience with QFD</i>	Little to none	Good deal of experience and training
<i>Type of development process</i>	Traditional (functional)	Concurrent engineering
<i>Was QFD Customized?</i>	No	Yes

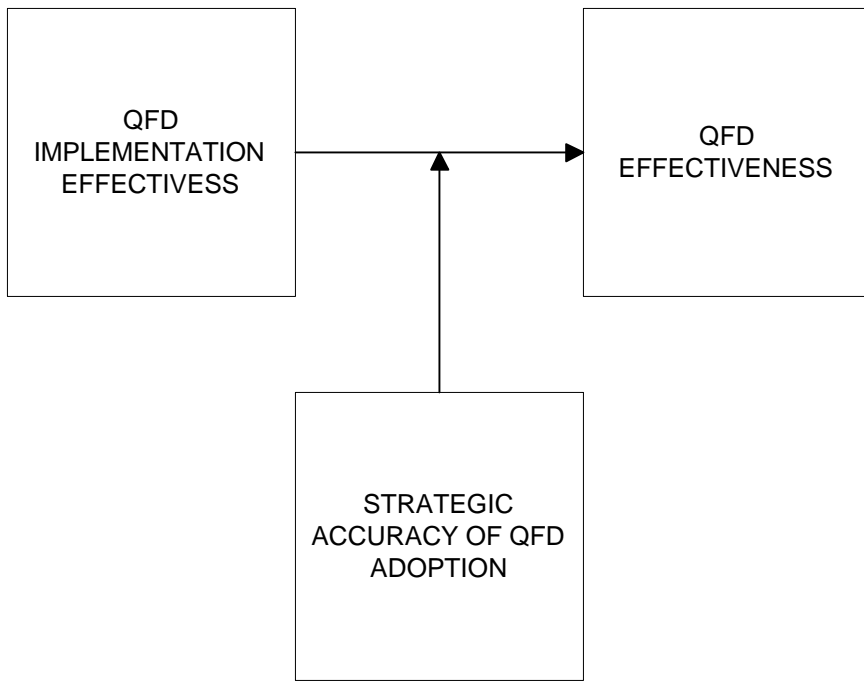


Figure 1 A Model of QFD Effectiveness