Division of Research
School of Business Administration

April 1992

INTEGRATING PRODUCT DESIGN THROUGH QUALITY FUNCTION DEPLOYMENT: IMPLEMENTATION AND PERFORMANCE

Working Paper #683

Anil Khurana
and
Archie Lockamy III
The University of Michigan

Integrating Product Design Through Quality Function Deployment : Implementation and Performance*

Executive Summary:

Shortening new product lead times while improving product quality is a major challenge facing U.S. manufacturers, especially in the auto industry. Product design is already a competitive priority for Japanese manufacturers (Miller, Kim, Meyer, Ferdows, Nakane and Kurosu, 1990) who have developed a new philosophy for it - quality function development (QFD). QFD combines various design engineering and managerial tools via teamwork to create a customer and value-based business philosophy. The Japanese version of QFD appears complex, but is actually based on the simple philosophy of giving customers what they want : high quality and desirable product functions at a reasonable price.

QFD can play an important strategic role for a business by helping it develop excellent products quickly and at low cost. QFD aims to "delight" the customer by incorporating his/her voice into the product design process. As with most Japanese management philosophies, QFD requires a major change in organizational culture. Thus, QFD can best be implemented as part of a broader total quality management (TQM) philosophy. Teamwork along with top management awareness and support are essential to the success of QFD. Also, QFD teachers, advocates, and facilitators can ease the transition from the "chimney-style" organizational model for product design to the QFD-based teamwork model.

The purpose of this paper is to describe QFD implementation as a part of the product design process. First, we illustrate the strategic role of QFD, and the need for top management awareness and support. Next, we present a description of the QFD methodology. This description can be useful to product managers struggling with ways to

* We would like to thank Chrysler Motors Corporation for supporting this research effort. Special thanks go to Mr. Robert J. Dika, Mr. Glenn W. Czupinski, Mr. Chris W. Kurowski, and Mr. Alan C. Carlson for sharing valuable comments, insights, and knowledge about the product design process in the auto industry.

improve the product design process. Third, we describe the process of implementing QFD. Finally, we suggest organizational requirements for implementing QFD and measuring its effectiveness.

Given the comprehensive Japanese approach to design and the inherent complexity of the product design process, it is vital that QFD implementation complements the firm's business strategy, and involves the organization's engineering, manufacturing, marketing, and quality functions. QFD implementation also relates to organizational readiness. This means creating an environment of functional integration and program stage coordination (e.g. Cadillac uses teams to achieve this), and developing consistent operational measures of performance across these design stages.

One of the conclusions of our study is that an appropriate performance evaluation system is needed for QFD and the product design process. Most Japanese descriptions of QFD indicate the need for feedback on designs from upstream organizations so that the product design is updated as it moves along the design timeline. A framework for incorporating design feedback mechanisms in the product design process is provided in the paper. These feedback mechanisms can also enhance the performance evaluation process - both for the design team, and for QFD as a program. Product design managers may find this framework useful in managing design projects successfully.

Integrating Product Design Through Quality Function Deployment : Implementation and Performance

I. Introduction:

Various factors point to the need for a major change in the management of the product design process in most U.S. companies. Customers desire quality and value at a reasonable price. They also want technically sophisticated products. Successful global competitors must consistently design and produce products of high quality and low cost. To further differentiate themselves, these competitors continuously reduce the time to market of their new products (Stalk and Hout, 1990). Also, it is now widely accepted that product cost, quality, and reliability are determined to a significant degree during the product engineering stage (Soderberg, 1989). Traditional U.S. product design processes are sequential and provide minimal support on the above-mentioned factors. A more holistic approach is required to provide customers with products that exhibit world-class quality, cost, and technology attributes, and are the first in the market.

Changes in the design process are critical to the survival of the U.S. auto industry. U.S. auto makers are faced with educated and discerning customers along with intense Japanese competition. They must enhance their product designs, lower costs, and reduce new product development lead times. General Motors Corporation, Ford Motor Company, and Chrysler Motors Corporation are making efforts to respond to this new competitive challenge through improvements in technology (e.g. CAD/CAM and robotics), design management (simultaneous engineering, design for manufacturing and assembly [DFMA], etc.), and organizational changes (cross-functional teams, consensus management, and employee empowerment). Product development lead times have been reduced from approximately 62 months to 54 months. However, Japanese auto makers develop new models in less than 36 months.

Comparisons between U.S., European, and Japanese auto makers have been provided through several research studies (Clark, 1989; Clark and Fujimoto, 1991). Researchers give various explanations for the Japanese advantage. Organizational commitment, supplier involvement in the design process, adoption of program management (versus functional approaches used by many U.S. auto makers), fewer engineering changes, and off-the-shelf predesigned vehicle components are some of the most frequently cited explanations. Clark and Fujimoto suggest that effective product development goes beyond the use of excellent tools, techniques and practices:

> *".. What seems to set apart the outstanding companies in product development .... is the overall pattern of consistency in their total development system, including organizational structure, technical skills, problem-solving processes, culture, and strategy."*

This consistency includes the need to design "for the customer". Such an approach leads to fewer design changes, lower warranty costs, and more satisfied customers. Instead of correcting problems, design teams can now focus on planning for strategic needs.

Our interviews with design engineers, manufacturing engineers, and product managers in US auto companies indicate that quality function development (QFD) provides a vehicle for developing consistency in the product development process. Carefully determined customer requirements form the basis of product design. Close interaction between different functions helps reduce the complexity of the design process. QFD also provides the necessary link between successive stages of product design.

In addition, QFD also plays an important role in appropriately allocating engineering and other resources to various stages of the design process. This is achieved by prioritizing product requirements based upon the customer's voice. With adequate resources, managers and functional specialists can resolve problems early in the design process. Design engineers need not compromise product specifications for manufacturing and assembly which result in costly field failures (Clausing and Taguchi, 1990). Companies that prioritize product requirements and allocate resources accordingly are likely to have better products that are also faster to the market. Figure 1 contrasts the product design resource allocation profiles for Japanese and U.S. companies. The Japanese spend more time and resources than U.S. firms in the initial stages by: (1) Developing a clear product strategy; (2) Carrying out rigorous product planning; (3) Improving manufacturing processes; and (4) Preventing design problems. The subsequent stages are then much easier for them to manage. This understanding explains the difference between the product performance of U.S. and Japanese firms. Whereas US firms are busy sorting out problems after the product has reached the customer's hands (thus incurring warranty costs), the Japanese set priorities based on customer input for the *next* generation of products.

Figure 1 here

The QFD Concept

Quality function deployment originated in Mitsubishi's Kobe shipyard in 1972, possibly as an outcome of Deming's teachings (Sherkenbach, 1988: p. 79). The original Japanese name was ***Hin Shitsu Ki No Ten Kai.*** The translation is given below:

Hin Shitsu	***means***	quality or features/attributes.
Ki No	***means***	function or mechanization.
Ten Kai	***means***	deployment, diffusion, or development/evolution.

The Japanese view QFD as a philosophy which ensures high product quality in the design stage (Akao, 1990). The aim is to satisfy the customer by ensuring quality at each stage of the product development process. Therefore, QFD should be viewed as a part of the total quality management (TQM) philosophy.

QFD helps companies identify real customer requirements, and translates these requirements into product features, engineering specifications, and finally, production details. The product can then be manufactured to satisfy the customer. QFD is an integrative philosophy which links together customer needs, product and parts design requirements, process planning, and manufacturing specifications during product development. Various tools and mechanisms are used to operationalize the QFD concept. For example, design for manufacturing and assembly (DFMA) is used as a part of the QFD philosophy. QFD can also help identify consistent performance measures for the different stages in the product design - process design - manufacturing - customer chain.

The benefits of QFD are: (1) Better customer satisfaction resulting from improved quality of design; (2) Shorter lead times due to fewer and earlier engineering changes; (3) Better linkages between various design and manufacturing stages; (4) A reduction in the number of product components; and (5) An improved work atmosphere through horizontal integration of functions (Sullivan, 1986). Also, QFD provides a structure for benchmarking competitor designs. Japanese auto makers attribute tangible benefits such as low product cost, high quality, and short development lead times, to QFD (Hauser and Clausing, 1988; Ealey, 1987). Engineering changes are fewer and take place earlier so that product lead times are reduced (Hauser and Clausing, 1988; McElroy, 1987). Thus, QFD enhances both the design process, and the underlying organization (Figure 2).

Figure 2 here

Purpose of Study

The purpose of this study is to describe the QFD process, and outline the organizational requirements necessary for successfully implementing QFD. As an extension we also propose a performance measurement model that facilitates QFD implementation.

The paper is organized as follows. Section 2 reviews prior literature on QFD and total quality management (TQM). The purpose of this section is to acquaint the reader with the QFD technique, and to stress that an effective product design strategy requires an organization-wide commitment to quality. Section 3 describes the research methodology used for this study. Research findings are presented in Section 4. These findings are discussed in Section 5. In this section, we propose a methodology for evaluating project performance and QFD success. Suggestions for implementation are also offered. Finally, conclusions and directions for future research are presented in Section 6.

II. Review of the QFD Literature

QFD and Total Quality Management

Total quality management (TQM) focuses on the continuous improvement of input-output effectiveness across the entire scope of the company (Feigenbaum, 1977). TQM has two perspectives: internal and external. The internal perspective requires top management commitment (Garvin, 1983; Deming, 1986) and organizational readiness for adopting total quality concepts (Garvin, 1984; Lele and Karmarkar, 1983). Additionally, TQM requires organizational policies consistent with the total quality philosophy (Garvin, 1983; Reddy, 1980). The external perspective requires a customer focus (Garvin, 1984; Crosby, 1980; Reddy, 1980). TQM facilitates customer satisfaction by focusing on three core business areas: (1) Management information systems; (2) Marketing and product engineering; and (3) Manufacturing. Management information systems provide data on quality costs and customer satisfaction. Marketing and product engineering use the TQM philosophy to help design and deliver a quality product to the customer (Lele and Karmarkar, 1983). TQM in manufacturing aims to achieve a defect-free production system. This is achieved by problem-solving in cross-functional teams, and the reduction of waste through continuous improvement activities.

QFD can be viewed as an application of the continuous improvement philosophy to marketing and product engineering, just as just-in-time (JIT) can be viewed as an application of TQM to manufacturing operations. Many U.S. manufacturers have already adopted JIT, initially as a shop-floor technique, and subsequently as a business philosophy. It is interesting to note that our research reveals a similar approach to QFD adoption by U.S. auto makers. In the initial stages of adoption, users viewed QFD simply as a design technique. Later, other functions in the organization recognized QFD as a design and business philosophy.

King (1989) describes QFD as one of fourteen concepts that are part of a TQM vision. McElroy (1989) views QFD as a comprehensive business planning tool, to be used in conjunction with Taguchi methods, statistical process control (SPC), and just-in-time (JIT). Using QFD ensures that nothing falls through the "cracks" in regards to the needs of the customer (Ealey, 1987). Further, QFD captures the voice of all customers in the product design process: end-users, regulators, dealers/retailers, downstream users in the company, suppliers, etc.

Elements of QFD

QFD consists of two components which are deployed into the design process: (1) Quality; and (2) Function. These components are consistent with the two strategic perspectives of TQM described in the previous section. The external perspective of TQM is implemented via "quality deployment", which brings the customer's voice into the design process. It ensures design and production quality by identifying design targets, and product and part specifications, that are consistent with customer requirements. "Function deployment" links different organizational functions and units in the design-to-manufacturing transition via the formation of design teams. Functional specialists are brought together to reduce miscommunication between design stages and functions. Since a team problem-solving approach is appropriate for complex issues (Van de Ven, Delbecq, and Koenig, 1976), QFD is a suitable method for designing complex products. Supporting these two components of QFD is the internal perspective of TQM, which provides the organizational culture and strategic support necessary for a successful product design strategy. This ensures the "system consistency" suggested by Clark and Fujimoto (1991).

The QFD Process

To understand the QFD process, it is necessary to examine how QFD fits into key elements of the overall product development cycle: timing, performance evaluation, and resource commitment. The product development cycle can be divided into 4 phases that are associated with key events and managerial review stages (Figure 3). Phase one, product concept planning, starts with consumer and market research and leads to a product plan: ideas, sketches, concept models, and marketing plans. Product design, the second phase, takes the product concepts and develops product and component specifications. Prototypes are built and tested. In phase three, processes and production tools are designed based on the product and component specifications. Pilot runs for production processes and tooling are made to ascertain manufacturability and production standards. Once problems in pilot runs have been resolved, the product enters production (phase four), after which it reaches the customer. At this point, customer feedback serves as inputs for the next generation of products.

Figure 3 here

QFD is a 4-phase process driven by the "voice of the customer" (Hauser and Clausing, 1988). Figure 4 depicts these phases as a series of matrices which translate the inputs (WHATS) into outputs (HOWS). The output of the previous phase serves as the input for the next phase. Before the start of the QFD phases, a QFD plan, also called a business planning matrix, is created. At this time, product targets on cost, quality, investment, weight, and timing are established based on general market data. This leads to the first phase of QFD. Phase 1 (the product planning phase - also called the "house of quality") uses customer requirements as inputs to derive functional objectives. The most critical elements are identifying the real customer needs, and developing relationships between customer needs, design requirements, competitive benchmarking, marketing information, and potential design tradeoffs (Hauser and Clausing, 1988). The "house of quality" is constructed by specifying customer needs and functional design objectives. The planning matrix describes the relationships between the customer needs and the design objectives. The goal is to include all design objectives that have significant positive relationships with the customer needs. Current design characteristics are benchmarked against major competitors to identify major strengths and weaknesses. Relationships between design objectives are represented by a relationship matrix, or "roof" matrix, positioned at the top of the "house of quality" (Hauser and Clausing, 1988). Design objectives exhibiting a positive relationship are compatible with each other, and do not impose new design challenges. If the objectives exhibit a negative relationship, attempts are made to solve the problem through focused research on that issue. "Bottleneck engineering" is the name the Japanese give to such efforts to simultaneously achieve conflicting objectives (King, 1991). Finally, based on an analysis of customer needs, competitor capabilities, and the matrix relationships, engineers develop final design objectives (also see King, 1989).

Figure 4 here

Closely related to the product planning phase is the concept selection process. Concept selection helps engineers develop system and subsystem level design concepts which resolve design tradeoffs, and achieve overall product goals (Figure 5). Phase 2 (the part deployment phase) uses the functional design objectives obtained in phase 1 to identify parts requirements. Phase 3 (the process planning phase) translates the parts requirements into process requirements. Finally, phase 4 (the production planning phase) converts the process requirements into shop floor control requirements. During each of these phases, various tradeoffs may need to be made due to conflicting requirements. The concept selection process is used to balance pros and cons of alternative designs within the context of overall design objectives.

Figure 5 here

QFD Enhancements

Recently, improvements to the basic QFD process have been proposed (Clausing and Pugh, 1991). A description of some of these business and engineering enhancements in constructing the linked QFD phases is also given by Akao (1990). These improvements, which form part of the enhanced QFD (EQFD), are directed at providing better mechanisms to help design engineers to translate the WHATS into HOWS. For example, during phase 2 of QFD, a number of problems may arise, such as resolving tradeoffs, identifying traditional or innovative solutions, and choosing between alternatives. Useful tools to resolve such problems include the Pugh concept selection matrix (Clausing and Pugh, 1991), design of experiments, and bills of materials. The presence of design and manufacturing engineering representatives on the QFD team is desirable to integrate product and process engineering through design for manufacturing and assembly (DFMA) concepts. At the completion of this phase, product specifications and blueprints are generated. During phase 3, tools such as FMEA (failure modes and effects analysis), design reliability analysis, and DFMA (design for manufacturing and assembly) are used. DFMA is essential to all phases of the QFD process, but it is specifically useful in phase 3. A step-by-step description of these phases is given in Figure 6.

Figure 6 here

A New Research Focus

The above discussion reveals that prior research on QFD has focused on studying the QFD technique itself (e.g. Hauser and Clausing, 1988; Clausing and Pugh, 1991). A shift in research to evaluating implementation is now required. As more companies start implementing QFD, the task of identifying the keys to successful implementation and setting benchmarks becomes more important; at the same time, such research becomes more feasible. This paper is an exploratory study of QFD implementation.

III. Research Methodology

Since the central purpose of this research was to study the process of implementing QFD, a qualitative research methodology was adopted. We conducted a detailed case study of the QFD process applied to two different vehicle programs within Chrysler Motors Corporation (Chrysler). Most of our observations were confirmed during our discussions with engineers from Ford Motor Company (Ford). As mentioned earlier, our intent was to study the role of QFD in the product design process for the U.S. auto industry. Chrysler was used as a case study for exploring QFD applications in the U.S. auto industry for several reasons. First, Chrysler had recently reorganized its product lines into design platforms, which provided a level of organizational readiness consistent with the effective use of QFD (The Wall Street Journal, 1992). Second, some areas within the firm had adopted the TQM philosophy prior to using QFD, which also improved the chances of observing effective QFD practices. In other areas, QFD actually helped the subsequent adoption of TQM. Finally, although Chrysler is the smallest of the U.S. auto manufacturers, it is still representative of U.S. industry practices. In general the firm has similar project timelines, similarly trained design engineers, and a similar organization structure. Chrysler uses the same QFD training programs as Ford and General Motors. It also uses the same software for planning, monitoring, and controlling QFD-related activities. Furthermore, its QFD program has an ongoing relationship with both Ford and General Motors.

QFD was formally launched at Chrysler on September 30, 1986, though the first application started on June 17, 1986. Initially, only a few of the cross functional teams embraced the QFD philosophy. Later, some of the product managers recognized the potential of QFD and implemented it for their vehicle programs. After the reorganization of Chrysler's product design into design platforms about three years ago, QFD found more and more support from senior managers. At present, two of Chrysler's most important car platforms subscribe to QFD, and another is getting ready to fully adopt QFD.

The American Supplier Institute (ASI) provided QFD training for Chrysler during the first few years. Recently, this role has been taken over by Chrysler's Quality Planning Group. During the formative years of QFD at Chrysler, the company also sought the help of well known Japanese quality, design, and QFD gurus such as Akashi Fukuhara (Assistant Director, Central Japan Quality Control Association).

The Chrysler study included ten semi-structured interviews with program managers, design and manufacturing engineers, QFD team leaders, QFD specialists and facilitators, and DFMA specialists. Each of these interviews lasted for one to three hours. In addition, we had extensive discussions with the QFD Planning Group at Chrysler. Of great benefit was the close interaction we had with active QFD teams. Chrysler engineers motivated the researchers to "live" the QFD process in order to get a better feel for the working philosophy. The researchers participated in the weekly meetings of one of the QFD phase 1 teams. In addition, we attended meetings of a QFD phase 3 team, which comprised of program management, design, advanced engineering, logistics, and plant management representatives.

Another source of information at Chrysler was company data. Documents pertaining to product policy, supplier meetings, and marketing feedback were reviewed. Chrysler also shared company manuals, QFD charts, and information on past QFD teams. The researchers also benefited from attending Chrysler-sponsored QFD training sessions.

IV. Research Findings

Our research findings encompass two areas: (1) The QFD implementation process; and (2) Strategic issues in QFD implementation.

QFD Implementation

In the following paragraphs, we first describe implementation of the QFD technique. The section on "adoption of QFD" addresses organizational issues in QFD implementation.

Implementing the QFD technique

The QFD Process. The case study and interviews revealed how QFD is actually implemented. For example, figure 5 showed the concept generation process. At the business planning stage, the concept generation is implemented by initially starting with a program management level team that sets overall guidelines, and allocates responsibility to different design groups for different systems. These design groups then set up QFD teams which start by looking at the system-level needs. Once these requirements are established, the team breaks up into smaller groups that focus on different components. At the same time, there is progress on the "horizontal" phases of the QFD process. The system-level QFD team still maintains overall responsibility for the system. The simultaneous "vertical" (disaggregation of concept selection) and "horizontal" phases of the QFD process support the "rugby" approach to product design (Takeuchi and Nonaka, 1986).

QFD Software. In order to keep track of the different QFD teams, their responsibilities and their progress, some QFD teams at Chrysler use a commercially available QFD software package. Several of these software packages are commonly used. With minor differences, these software have the capability of constructing and analyzing the "house of quality" and other QFD matrices. Use of such software is still not very popular in the product groups that we visited. Often, it is the responsibility of the QFD facilitators/coordinators to maintain the QFD charts.

Making Design Tradeoffs. What happens when customer requirements lead to conflicting design requirements? Although such conflicts may occur during any of the four QFD phases, they are most likely detected as negative correlations in the roof of the "house of quality". Engineers at later design stages must be made aware of such conflicts - managing information transfer and communication is the key to resolving such conflicts.

Two kinds of solutions to such tradeoffs normally occur. The first uses the approach suggested by the Pugh concept selection method. In this approach, alternatives are generated, and the best alternatives are chosen based on the previously set cost, quality, weight, investment constraints and objectives. Failure mode and effects analysis (FMEA) is used to challenge the best design alternatives to expose their weaknesses and to find potential problems. However, the best alternatives may still not be very attractive. The second approach may be useful in such cases. Taguchi design of experiments can be used to "optimize" the design by isolating controllable variables. By determining the effect of these variables on the design requirements, it is possible to determine optimum levels for controllable parameters. By understanding the behavior of certain design outcomes as a function of these controllable parameters, mathematical optimization (such as linear/non-linear programming) can be used to determine optimal parameter settings and design outcomes.

Going into this project, the researchers had expected to observe an additional benefit from using QFD. Since QFD brings together a multi-functional team, and helps challenge traditional design objectives and targets, the researchers expected an increase in design innovations resulting from the need to make such design tradeoffs. A few examples do exist. For example, the new cruise-control device on the new LH mid-size cars is an improved version resulting from such conflicting design objectives. However, discussions with several QFD design teams revealed that such innovations have not yet become common. Managers were confident that such a benefit would occur soon. The researchers hypothesized that this may be happening because most of the engineers may not have fully accepted QFD as a basic design philosophy, and use it primarily as a design tool. This hypothesis was confirmed through discussions with several design engineers and managers. Another reason may be that the advanced engineering group, which is often the source of manufacturing and design innovations, is not yet an intimate part of the QFD concept.

Getting data for QFD. We mentioned earlier the importance of getting the real customer's voice into the product design process. However, due to various resource constraints, Chrysler management is sometimes unable to authorize first-hand customer research. In such cases, teams are encouraged to document what they know based on their experience, and only research where they do not know customer requirements, or feel that there is a risk of misinterpreting customer needs. Often, team members simulate customers by actually evaluating competing vehicles, and reviewing customer ratings.

Adoption of QFD

Adoption of innovations or new technologies is described as a 4-stage process: identification, transfer, amplification, and acceptance (Tornatzky et al., 1983). QFD can be viewed as an engineering design (or design administration) innovation. Implementation of QFD, therefore, requires an analogous process. At Chrysler, for example, the first time implementation of the QFD philosophy is viewed as a 4-stage process. The 4 stages are: (1) Spreading awareness; (2) Developing successful case studies and examples to motivate subsequent teams; (3) Company-wide training and education on QFD techniques and philosophy; and (4) Adoption of QFD as a business philosophy (Figure 7). However, each company must tailor these stages to its own culture.

Figure 7 here

During the "identification" stage, the goal is to identify the relevance and applicability of QFD to the particular organization. The required effort and organizational change is estimated. The second stage involves the "transfer" of the QFD technology and philosophy to managers and engineers. Managers must be made aware of the requirements and benefits of QFD, and engineers must be trained in specific QFD techniques. QFD works best in a cultural environment that practices total quality management (TQM). The researchers found that QFD teams were often trained in TQM and related techniques before implementing QFD. Since the product design process interacts with all segments of the organization, company wide TQM is desirable. Often, however, as some Chrysler engineers found, using QFD, first as a tool, then as a business philosophy, are developmental steps towards a TQM mindset. Organization, however, is a key ingredient. Without a legitimate horizontal structure like a platform organization or program management teams, it is very difficult to get full cross-functional participation (Dika, 1992).

The next stage is that of "amplification" -- highlighting the benefits, and gaining more supporters. In the initial stages of any program, the task of convincing managers becomes easier if there is some evidence of past success. The development of successful QFD case studies facilitates QFD adoption throughout the company. Once QFD is known and used company-wide, people accept QFD as a business and design philosophy. QFD is no longer viewed as requiring "extra" effort by its users, and becomes the standard approach to designing products and managing the business. Thus "acceptance" is achieved.

Strategic Issues in QFD Implementation

<u>Strategic Role of QFD</u>

QFD can play an extremely important strategic role for a company that depends on successful product design. It is widely accepted that effective and innovative product designs are critical for competing in the auto industry today (Miller et al., 1990; Clark and Fujimoto, 1991). QFD helps firms achieve a product differentiation strategy based on improved customer satisfaction along product design and performance characteristics. The QFD process leads to superior performance on competitive priorities such as product quality, customer service, and timely new product development. QFD also supports the achievement of these strategic priorities by bringing consistency and harmony to the design-manufacturing-customer feedback process. Its emphasis on teamwork broadens the understanding and responsibility of design and manufacturing engineers. By stressing the importance of the customer, whether internal (program stages or functional departments) or external (distributors and end users), QFD acts as a catalyst for change in the organizational culture. QFD strives to achieve an organizational culture based on teamwork and integration, continuous improvement, and a customer focus. From a strategic perspective, QFD has two benefits. First, it supports the organization's capability to compete on well-designed products by enhancing the product's value to the customer. Second, the cultural change that QFD brings about affects the way in which the organization operates.

To understand the strategic role that QFD actually plays for a company, micro-level phenomenon must be examined. Does QFD have program management's support and commitment? Does it lead to a continuous top-down bottom-up exchange of information? Does it really serve the purpose of bringing together individual engineers to form a cohesive team, or is it viewed as extra work? Does management use QFD to revise design targets, speed up project deadlines, and monitor design performance? To what extent does QFD enable design engineers to challenge long-accepted design concepts and standards? How well does QFD interface with other programs such as simultaneous engineering, DFMA, and SPC? How can managers ensure that QFD really meets customer requirements? These are some of the questions that can determine the extent to which QFD has a strategic impact on the firm.

Performance Evaluation Systems for QFD

Our interviews with Chrysler managers revealed that records relating to QFD and project performance were rarely kept (the story is not much different at Ford or GM). Part of the reason was the lack of an established evaluation system suited to QFD. Also, the evaluation of design engineers was not always consistent with QFD objectives. A senior program executive mentioned that establishing merit and reward systems consistent with QFD and other team-based programs has been a challenge. Creating a performance measurement system that is consistent with organizational and program objectives is clearly difficult. However, the success of any program depends on measuring performance and using it to provide constructive feedback. Examples of controls used for traditional (e.g. construction) projects are budgetary and time variances. Given the strategic role that new product development has in the U.S. auto industry, it becomes increasingly important to establish a performance evaluation and feedback system for product design and QFD.

V. Discussion of Research Results

QFD is more than a tool, it is a design philosophy

We have mentioned that one of the prerequisites for successful implementation of QFD is a TQM mindset in the QFD team. Our interviews with design engineers in one of Chrysler's vehicle platforms revealed that they often viewed QFD as a somewhat organized approach to product design. However, they felt that it was simply a substitute for Chrysler's previous approach. Since it was not an integral part of the overall design process, the perception was that it required additional time and effort. Such opinions lead to organizational and perceptual barriers in the success of QFD. These would not arise if QFD was viewed as a design philosophy. This view is consistent with the experience with most successful past and current Japanese philosophies - quality circles, TQM, and JIT. Also, the story of JIT implementation in the U.S. points to the need for adopting the complete philosophy (Myers, 1987). This also emphasizes the need to adapt the techniques to the organization's culture and needs. As an example, in one of Chrysler's QFD successful case studies, improvisations to the QFD process were carried out by the team itself. Thus, it is necessary to recognize the need for treating QFD as a design and business philosophy, and to adapt the technique to the organization's needs. Having a TQM philosophy in place in the organization facilitates the process.

Getting data - the need for a QFD information system

We mentioned earlier that due to various resource constraints, Chrysler management encourages teams to document what they know based on their experience, and only research where necessary. However, many companies identify changes in customer needs only after it is too late. Thus, using engineering experience alone as an input to QFD may be risky. Discussions with academics and practitioners who know other industries intimately revealed that industrial engineers can play an important role in ensuring a customer-based focus. Industrial designers are not mere "stylists", but are trained to use competitor analysis, user observations, and idea generation in creative and unique ways.

Getting QFD customer information is critical. Secondary data (from private reports or warranty data) only serve to confirm customer input, not substitute it. Such sources can only give information on points of customer dissatisfaction in the past, not what customers want in future products (Garvin, 1991). An innovative and efficient way of getting customer input may be to use market research and market segmentation studies as starting points for identifying customer needs. Detailed follow up customer studies can then be undertaken for critical issues. This is exactly what Toyota does in Japan. Since Toyota owns its own distribution channels in Japan, it sends staff members from the appropriate distribution channel on loan to product development teams. These channel staff members, through their customer-focus, know a lot about customer needs and attitudes. They influence not only demand forecasts, but also the characteristics of the next generation of Toyota automobiles (Womack, Jones, Roos, and Carpenter, 1990).

Generating customer inputs is not enough, though. QFD also needs a supporting information system for other reasons:

(a) Track the progress of the QFD project.

(b) Provide a link between the different phases of the QFD process.

(c) Record the performance impact of QFD by tracking engineering change orders (ECOs), productivity of engineers, number of drawings made, reduction of product costs as designed, improvement of design quality, etc. A comparison of non-QFD and QFD projects can be made to bring out the product and systemic advantages stemming from the use of QFD.

This information system ought to be linked to the QFD software being used so that all the information is linked, and is accessible to all engineers and managers. Mizuno (1988, p 81-82) provides further guidelines on how to manage a quality information system. He suggests that the information management group should keep in mind who the customers of such information are, and how they might use it. Also, it is the responsibility of this group to devise ways to disseminate this information.

Requirements for Successful QFD Implementation

Based on our findings and our review of the literature, the following preconditions for implementing QFD have been identified and are given below:

Organizational Culture

(i) A total quality management (TQM) mindset should exist in the QFD group. Such an environment ensures that everyone views the customer as the most important business consideration, and views QFD as a tool for continuous improvement. Thus, QFD provides a framework for the use of the appropriate design and quality tool.

(ii) The organizational unit implementing QFD should adopt a team culture. There are two reasons why QFD teams are essential. First, a team provides the necessary "mass" for generating new ideas. Second, the collective experience of the multifunctional team helps resolve complex design and business issues. Having various functional representatives on a team leads to faster decisions.

(iii) The success of QFD depends on the presence of a team leader who sets the team mission, visualizes team objectives, actively recruits new team members, and motivates team members to participate fully. Often, the team leader is a "champion" for QFD.

(iv) The first-time QFD teams should consist of strongly motivated and capable people. These teams will eventually set an example for future teams. The team may have a different composition depending on what phase of the QFD process is being addressed, the experience of the team members, and the business goals. Based on our discussions at Chrysler, we present Figure 8, which gives the team compositions at different stages of QFD.

Figure 8 here

Top Management Support

(v) QFD depends on support and assured participation from non-engineering functions. Thus, top management support is vital. The alternative is local sponsorship of QFD by a person in authority, so that QFD team participation is a legitimate job activity of the team members. This also ensures that the recommendations of the QFD team can be formally implemented. The sponsoring person should have some authority or influence over other functions too (e.g. platform or program managers). During our study at Chrysler, we were able to compare two QFD teams from different platforms. Only one of the teams had complete management support at the program level. The QFD team that had management's support had made QFD an inherent part of its approach to product design. They had the confidence to make decisions and bring other functions onto the team. In contrast, the other QFD team, lacking full support, viewed QFD as extra work. The members had difficulty coordinating, and the team leader found it difficult to ensure the participation of other functions.

(vi) Senior management commitment is necessary for another reason. QFD involves decision-making as a team. Since managers and executives cannot participate on more than a few business planning teams, this implies substantial delegation of authority to the design teams. Thus, management must have complete trust in people. This includes their own design engineers as well as suppliers. Such delegation of design decisions also leads to a change in the nature of the manager's job. Instead of making final decisions on design issues, the executive has more time to plan ahead, and coordinate important activities. For some managers, this may come as a shock. Thus, senior design management needs to prepare themselves for a change in responsibilities resulting from the implementation of QFD.

Facilitators and Coordinators

(vii) Successful QFD requires the presence of facilitators who can guide the team through the QFD process. This includes: (1) Teaching team members the QFD philosophy and techniques; (2) Ensuring proper use of QFD tools to prevent the team from getting bogged down by the complexity of the techniques (e.g. house of quality, design of experiments, DFMA); (3) Helping teams with data sources; and (4) Ensuring that relevant functions are represented on the teams.

(viii) Our interviews with design and manufacturing engineers, and product planners revealed the need for a coordinator, who would be closely associated with the component part or sub-assembly as the QFD process moves along. Such a person would ensure:

  (a) Continuity of the design concept for the assembly/system, subsystem, and component level.

  (b) Consistent goals and performance measures at the different QFD phases.

  (c) Timely progress of the system/subsystem design.

  (d) Involvement of other teams and programs at different phases - e.g. DFMA teams, statistical process control (SPC) planners, quality circles.

An alternative would be to ensure that the QFD teams at different phases interact during the transition phase where the next team takes over from the current QFD team. However, irrespective of the mechanism used for QFD phase-to-phase coordination, a program management organization is needed. This implies a formal or informal matrix structure, organized by function and product. Practical experience suggests that the product team-leaders should have substantial power to overcome functional barriers (Clark and Fujimoto, 1991: p. 254; The Wall Street Journal, 1992).

Performance Incentives

(ix) Implementing QFD also means that design and manufacturing engineers cannot be evaluated on the basis of existing measures of individual performance. Since performance is team-related, traditional approaches to rewarding merit and giving promotions must be changed. The performance measurement system must motivate people to become team players (Sherkenbach, 1988). Additionally, different functions often develop their own approaches to evaluating and rewarding performance. With teams, consistency of performance evaluation and reward systems is essential. Finally, QFD ensures continuity of the design process through the different "horizontal" stages. This means that the ultimate measure of performance of the team should be customer satisfaction. QFD leads to a direct relationship between business performance measures and personnel evaluation measures. An important link between business and operational measures of performance can thus be established (Kaplan, 1991).

Information Requirements

(x) Last, but most important, QFD requires data and information about customer needs. In instances where the firm does not have a good customer database, creating a separate information system for QFD implementation may be necessary. Customer research based on first-hand customer interviews, market analysis, consumer psychology, etc. is one of the best approaches to improve product designs.

Akao (1990) recommends that the best method is NOT to "play it by the book". Since each company's conditions are unique, it is important to be imaginative in applying the rules and to find a method suitable to the company. As an example, even though QFD is a structured process, Chrysler engineers in some of the design groups have adapted QFD so well to their needs that they skip phase 2 of the QFD process, and proceed with phase 3.

Measuring QFD project success

We mentioned earlier that records relating to QFD and project performance were rarely kept. For one, engineers and managers may find it difficult to clearly identify the performance measures, and the stage(s) of the design process where such measures should be tracked. Due to this lack of suitable performance indices, it becomes difficult to provide constructive feedback. The importance of a performance measurement system, and a proposed model to set up such a system is provided in the following paragraphs.

There are three elements which comprise a performance measurement system: performance criteria, performance measures, and performance standards (Crawford, Cox, Blackstone, 1988). The system must monitor strategic objective performance criteria using measures and standards based on current and future market requirements (Stalk and Hout, 1990). A performance measurement system must also contain mechanisms for ensuring consistent actions on shared objectives between organizational levels and across functional areas (Lockamy and Cox, 1992). Cyberneticists refer to processes exhibiting such strategy modifying and solution generating characteristics as "third-order feedback control systems" (Dixon, Nanni, and Vollmann, 1990). A third-order feedback system can reflect upon past decision-making. It collects and stores information, examines it, and formulates new courses of action. Third-order feedback systems are also self-organizing (Schoderbek, Schoderbek, and Kefalas, 1990). This means the system constantly adapts by altering products and services, policies, processes and structures. Since information provides the vehicle for self-organizing systems to function, not only are feedback processes depicting the present state of the organization necessary, but also feedforward processes providing information on the anticipated future state of the environment. Therefore, information is required concerning the interaction of the organization with the environment.

Division of work exists even within the same department in a firm. As a result, in order to ensure that different responsibilities are coordinated, and focused on achieving strategic objectives, mechanisms are required which provide horizontal linkages between the different work units or stages. Performance measurement system linkages promote "organizational focus", whereby the actions and behaviors of the firm concentrates on objective achievement, decisions follow a consistent pattern company-wide, and a pervasiveness exists in the firm to support those activities necessary for successful objective completion.

The product design process is complex and requires months of effort. It would be difficult, and also too late, to measure the end result of the product design process when the product actually reaches the customers. QFD structures the process and helps establish distinct stages at which reviews can be conducted. In the words of Fukuhara, it creates the "ability to horizontally integrate by creating visual documents that could be read by people from all over the company" (Ealey, 1989).

QFD based performance measures can be utilized from two perspectives. First, they can be used to control/monitor the performance of engineers, manufacturing planners, and other participants in the design process. However, QFD is part of the broader TQM and continuous improvement philosophy; both the TQM philosophy, as well as Deming (Sherkenbach, 1988; Walton, 1986) believe that measures of human performance should not be used as control devices. However, measurement systems can be used as motivators to stress teamwork rather than individual and functional performance (Heany and Vinson, 1984). QFD performance metrics can then be used as process measures to help the QFD team redefine future priorities and design tasks. They can also help determine where and how the QFD process can be improved. Lastly, tangible measures of success can help build management confidence and support for the design team's efforts. These measures can then replace case studies as demonstrations of success. In short, if QFD is a roadmap for design, the QFD measures serve as pathfinders and milestones.

The four design phases, though not discrete entities, can be considered as somewhat independent phases, especially since a transition in team structure often occurs between phases. Thus, the completion of each QFD phase can serve as a checkpoint where the design process can be reviewed. Figure 9a describes the information flows in the QFD process. The figure provides the basis for a conceptual framework for evaluating the success of a QFD-based product design process. QFD metrics based on expected benefits can help evaluate project progress by measuring the degree to which QFD benefits have been achieved. Using this approach, Figure 9b proposes a checklist and measures for each stage of the QFD design process. This can also serve as a starting point for future QFD studies which examine performance measurement issues.

Figures 9a and b here

Since evaluation of the measures often requires extensive effort and neutral agencies, the upstream QFD team should evaluate the success of the QFD design process after the downstream QFD team has completed its task. This can be viewed in the form of a feedforward loop, which also generates the feedback loop for the overall design, and for subsequent QFD design projects (Figure 10).

Figure 10 here

VI. Conclusions and Future Research

This research highlighted five key ideas at the core of QFD. *First*, QFD assumes that customer satisfaction is priority number *one*. No amount of customer/user research is too much while trying to get a better feel for customer needs. *Second*, QFD structures the design process so that critical issues are not neglected, and priorities are established. A supporting QFD information system is required. *Third*, QFD recognizes that product design works best with cross-functional teams. These teams help improve intra-organizational communication as prescribed by Deming (Walton, 1986). *Fourth*, the success of QFD also depends on the ability to provide feedback for the design process. This requires setting up a performance evaluation system. *Finally*, and most important, QFD can be successful if it is recognized that is a business philosophy as well as a design support tool. Its success thus depends on top management support.

In this research we first described the QFD process. Next, we discussed QFD implementation at Chrysler. Product managers and design engineers should find our presentation of the process of implementation of QFD useful. We also identified the desirable features of an information system necessary to support the QFD process. Finally, we discovered that few current implementations of QFD among U.S. auto manufacturers have a consistent performance evaluation system. Based on our knowledge of the QFD process, and prior research on performance measurement systems, we proposed a model that can guide program/product managers in setting up their performance measurement system.

Future research can be directed at benchmarking QFD and product design practices, identifying product design success factors, and identifying different kinds of performance evaluation systems that may be consistent with QFD requirements. This could be based on conceptual or empirical research. Our study can also be extended outside the auto industry to study best practices.

References

Akao, Yoji (ed). QFD: *Integrating Customer Requirements Into Product Design.* Cambridge, MA; Norwalk, CT: Productivity Press, 1990.

American Supplier Institute. *Quality Function Deployment - Implementation Manual For Three-Day QFD Workshop, Version 3.2.* Dearborn, MI:American Supplier Institute, 1989.

Clark, Kim B. "Project Scope and project performance: the effect of parts strategy and supplier involvement on product development". *Management Science*, October, 1989: 1247-63.

Clark, Kim B. and T. Fujimoto. *Product Development Performance - Strategy, Organization, and Management in the World Auto Industry.* Boston, MA: Harvard Business School Press, 1991.

Clausing and Taguchi. "Robust Quality". *Harvard Business Review*, vol. 68, no. 1, Jan-Feb, 1990: 65-72.

Crawford, Karlene M., James F. Cox, and John H. Blackstone. *Performance Measurement Systems and the JIT Philosophy.* Falls Church, VA: APICS, 1988.

Crosby, P.B. *Quality is Free*: The Art of Making Quality Certain. New York: McGraw-Hill, 1980.

Deming, W.E. *Out of the Crisis.* Cambridge, MA: MIT Center for Advanced Engineering Study, 1986.

Dika, Robert J. Personal communication, March 1992.

Dixon, J. Robb, Alfred J. Nanni, and Thomas E. Vollmann. *The New Performance Challenge: Measuring Operations for World-Class Competition.* Homewood, IL: Dow Jones-Irwin, 1990.

Feigenbaum, A.V. "Quality and Productivity". *Quality Progress*, vol. 10, no. 11, November, 1977: 18-21.

Garvin, D. "How the Baldridge Award Really Works". *Harvard Business Review*, vol. 69, no. 6, Nov-Dec, 1991: 80-95.

Garvin, D. "What Does Product Quality Really Mean?". *Sloan Management Review*, vol. 26, no. 1, Fall, 1984: 25-41.

Garvin, D. "Quality on the Line". *Harvard Business Review*, vol. 61, no. 5, Sept-Oct, 1983: 65-75.

Hauser, John R. and Clausing, Don. "The House of Quality". *Harvard Business Review*, May-June, 1988: 63-73.

Heany, D.F. and W.D. Vinson. "A Fresh Look at New Product Development". *Journal of Business Strategy*, Fall, 1984: 22-31.

Kaplan, R.S. in Kaplan, R.S. (ed.) *Measures of Manufacturing Excellence*, 1991.

King, Bob. *Better Designs In Half the Time*. GOAL/QPC, 1989.

Lele, M.M. and U.S. Karmarkar. "Good Product Support is Smart Marketing". *Harvard Business Review*, vol. 61, no. 6, Nov-Dec., 1983: 124-132.

Lockamy III, Archie and James F. Cox. *Critical Linkage: Aligning Performance Measurement Systems for Competitive Advantage*. Homewood, IL: Business One Irwin/APICS (forthcoming, 1992).

McElroy, John. "The House of Quality - For whom are we building cars?". *Chilton's Automotive Industries*, June, 1987: 68-70.

McElroy, John. "QFD - Building The House of Quality". *Chilton's Automotive Industries*, January, 1989: 30-32.

Miller, J.G., J.S. Kim, A.D. Meyer, K. Ferdows, J. Nakane, and S. Kurosu. *Factories of the Future*. Executive Summary of the 1990 International Manufacturing Futures Survey, 1990.

Mizuno, Shigeru. *Company-wide Total Quality Control*. White Plains, NY: Quality Resources and Asian Productivity Organization, 1988.

Myers, Scott M. "Don't Let JIT Become a North American Quick-Fix". *Business Quarterly*, March 1987:28-38.

Reddy, J. "Incorporating Quality in Competitive Strategies". *Sloan Management Review*, Spring, 1980: 53-60.

Schoderbek, Peter P., Charles G. Schoderbek, and Asterios G. Kefalas. *Management Systems: Conceptual Considerations*. Homewood, IL: Irwin, 4th ed., 1990.

Sherkenbach, W.W. *The Deming Route to Quality and Productivity: Roadmaps and Roadblocks.* Washington D.C.: CEEPress Books, 1988.

Soderberg, Leif G. "Facing Up to the Engineering Gap". The McKinsey Quarterly (Spring 1989): 2-18.

Stalk, George and Thomas M. Hout. *Competing Against Time.* New York, NY: The Free Press, 1990

Sullivan, L.P. "Quality Function Deployment", *Quality Progress*, June, 1986: 39-50.

Takeuchi, H. and I. Nonaka. "The New New Product Development Game", *Harvard Business Review*, Jan-Feb 1986:137-146.

Tornatzky, L.G., J.D. Eveland, M.G. Boylan, W.A. Hetzner, E.C. Johnson, D. Roitman, J. Schneider. *The Process of Technological Innovation: Reviewing the Literature*, Productivity Improvement Research Section, Division of Industrial Science and Technological Innovation, National Science Foundation, May, 1983.

The Wall Street Journal. "Long Road Ahead: American Auto Makers Need Major Overhaul To Match the Japanese", January, 17, 1992 (p 1).

Womack, James P., Daniel T. Jones, Daniel Roos, and Donna Sammons Carpenter. *The Machine That Changed the World*, Rawson Asociates, a division of Macmillan Publishing Company, 1990.

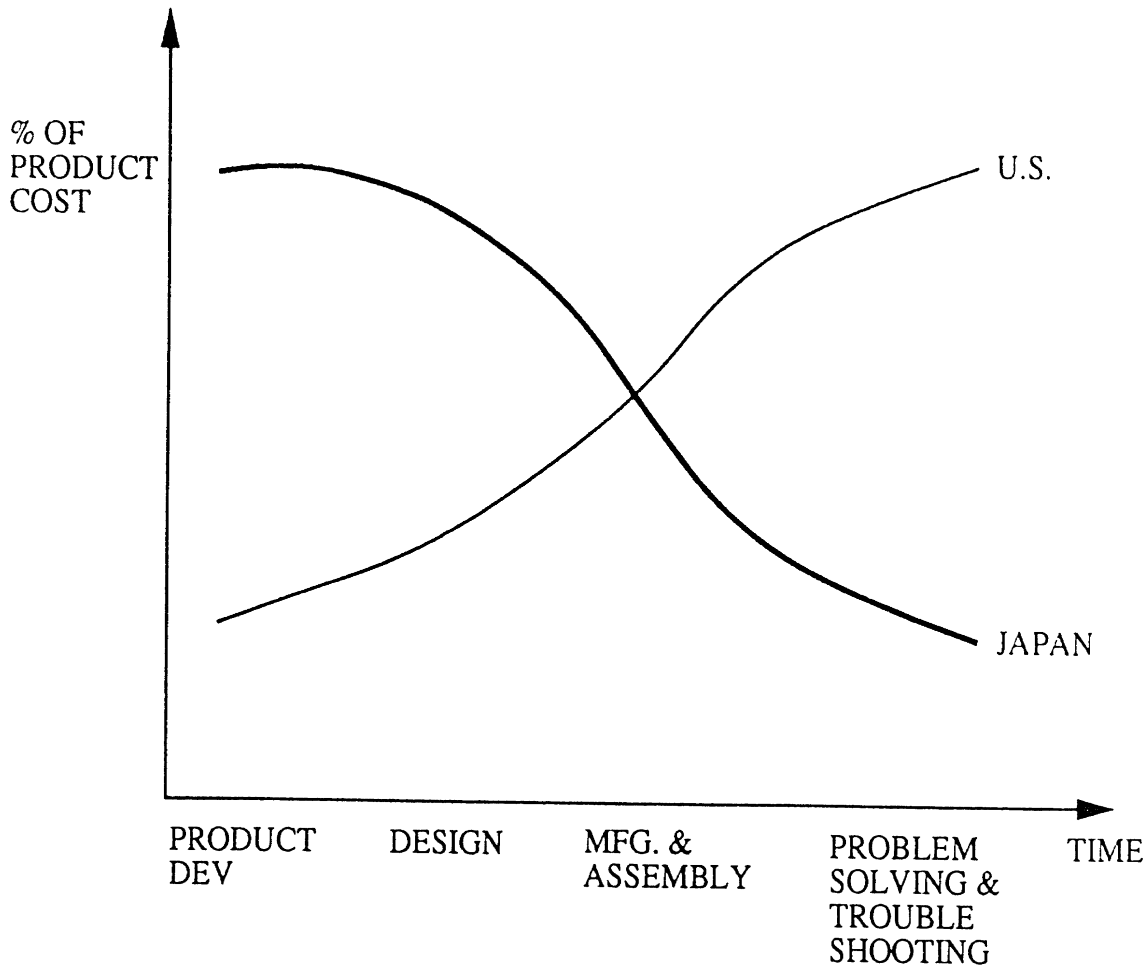

FIGURE 1

Resource Allocation Profiles for U.S. and Japanese Products

DESIGN BENEFITS

Fewer and early design changes

Less time in development

Fewer startup problems

Lower startup cost

Fewer field problems

More satisfied customers

Identifies comparative strengths and weaknesses of product with respect to competition

ORGANIZATIONAL BENEFITS

Encourages teamwork and participation

Encourages documentation of marketing, design, engineering, and manufacturing product knowledge in a consistent and objective manner.

FIGURE 2

Benefits of Quality Function Deployment

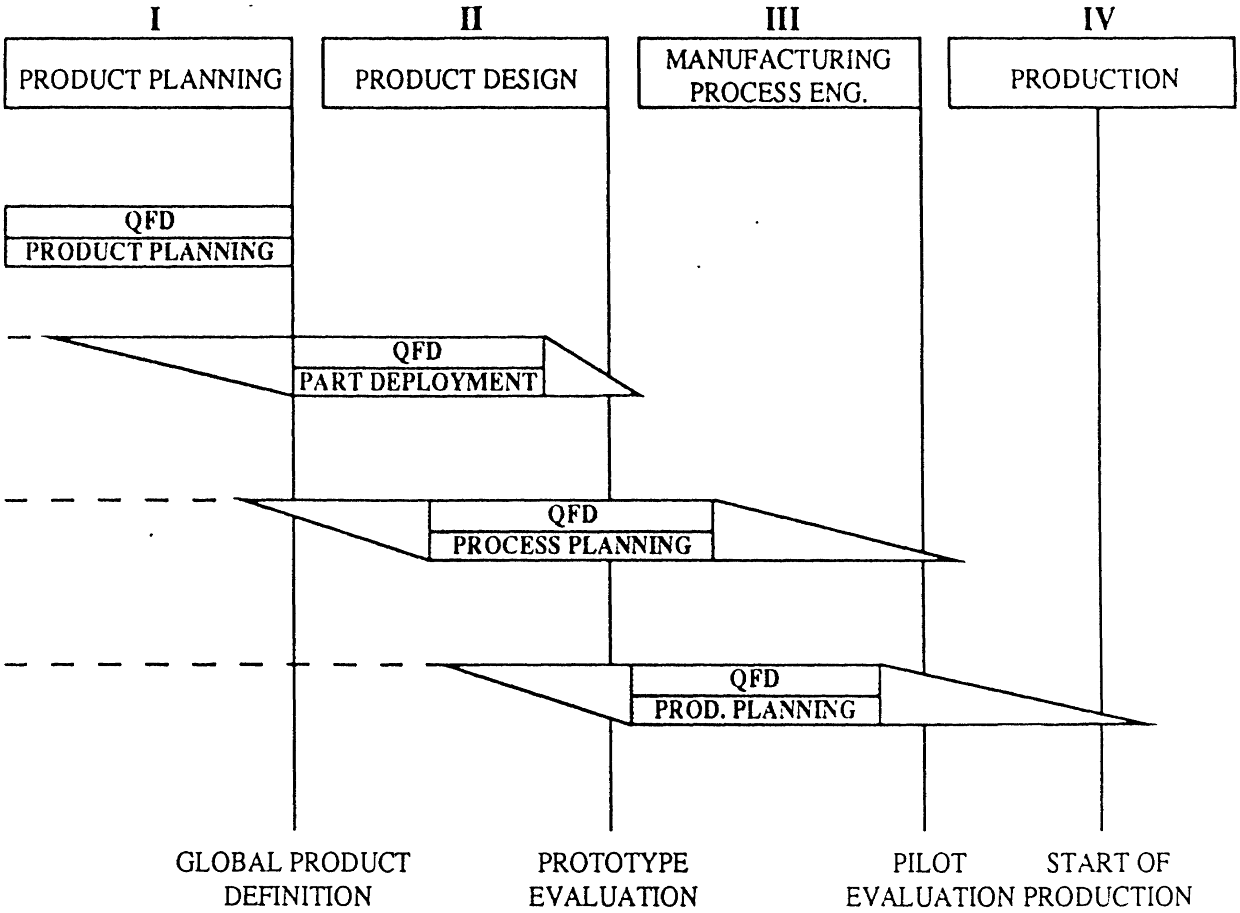

FIGURE 3

The Product Development Cycle and QFD--Key Events*
(Adapted from the Quality Function Deployment manual of the American Supplier Institute, 1989 and Chrysler's QFD manual.)

---

*These phases are common to all three U.S. auto manufacturers.

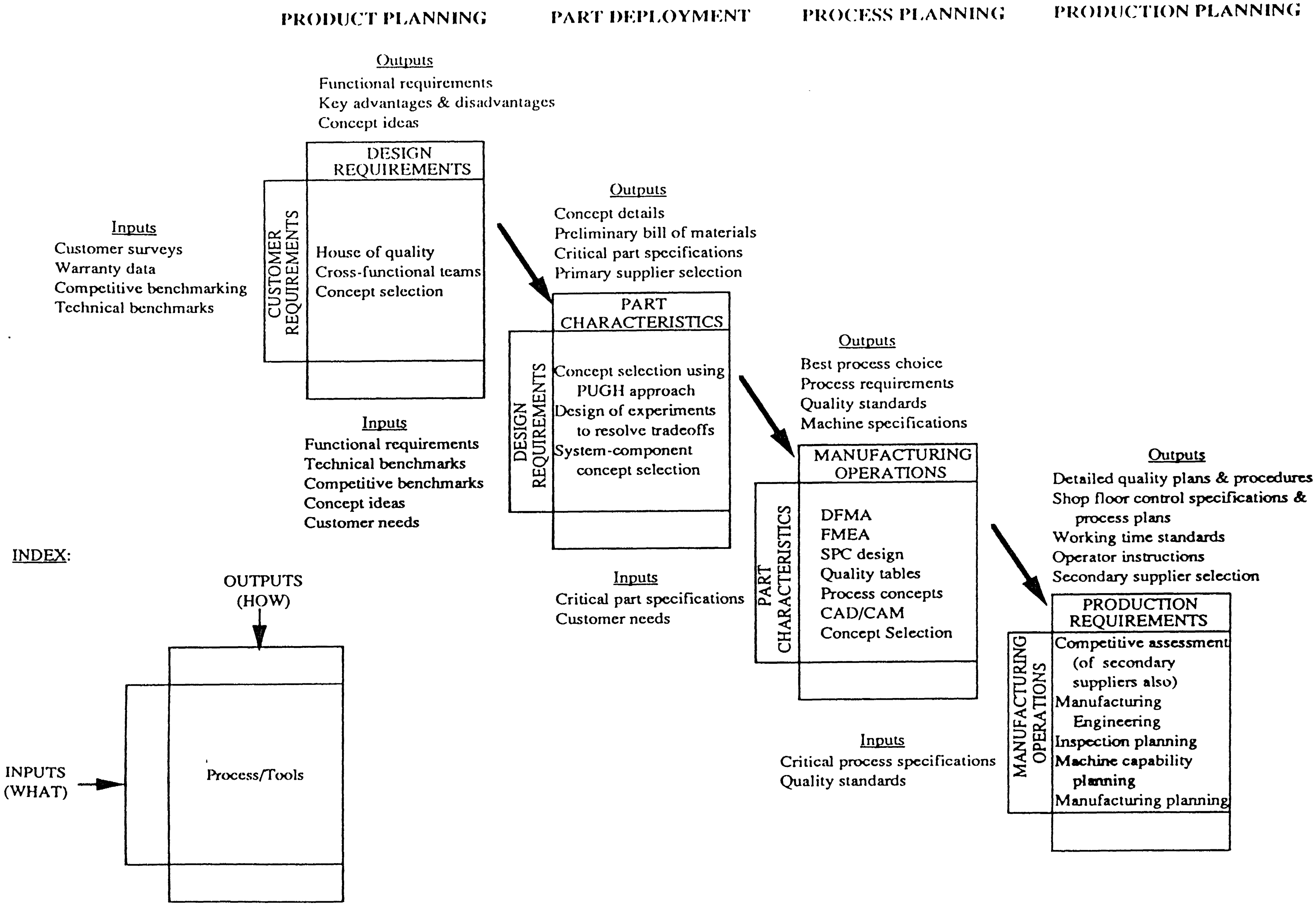

FIGURE 4

The QFD Phases

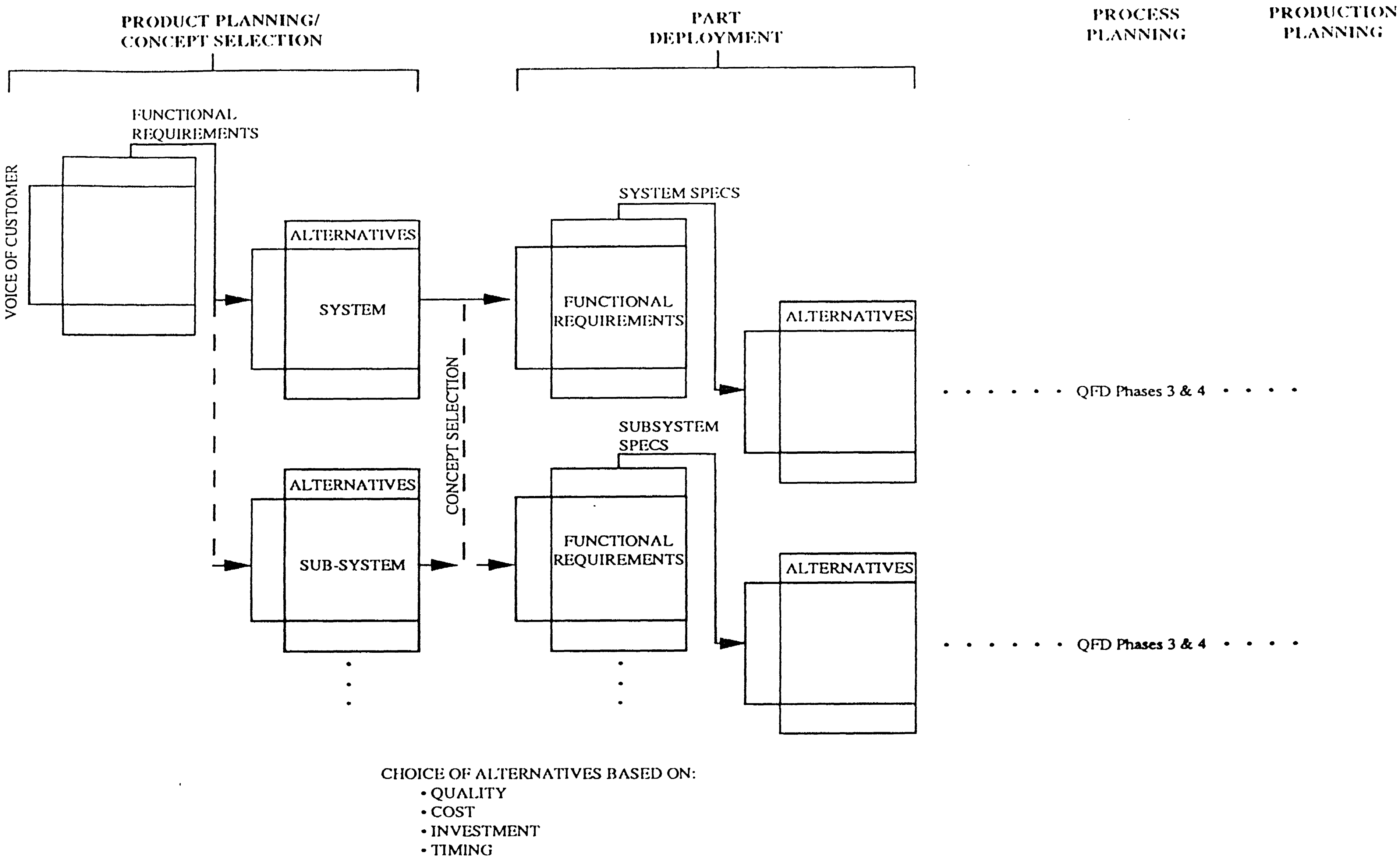

FIGURE 5

Role of Concept Selection in the QFD Process

Phase I - Product Planning

Identify customer needs; also detail regulatory requirements. Use customer surveys, and warranty and complaint data to describe these.

Define customer importance ratings based on surveys, delphi-based technological forecasts.

Select major customer needs. Focus on these as first priority. Establish overall design requirements.

Complete relationship between customer needs and design requirements.

Get data on competitive technical benchmarks.

Set preliminary design targets; look out for correlationships in the "roof" matrix.

Try to anticipate organizational difficulties in achieving targets.

Finalize target values.

Phase II - Part Deployment

Generate concept alternatives. Use competitor benchmarking, techniques such as Pugh's method, etc.

Select final concept.

Develop sub-component/ subassembly requirements (or Bills of Materials).

Get importance values for different functional requirements and complete relationship matrix.

Analysis using fault tree analysis, FMEA, etc. to help finalize target values for part characteristics.

Phase III - Process Planning

Generate process technology alternatives that can meet part characteristics; choose best alternative.

Construct flow diagram, determine critical process parameters.

Complete part requirements-process technology relationship matrix; calculate importance weights.

Optimize process to improve capability and reduce manufacturing process variations.

Finalize critical process parameter values.

Phase IV - Production Planning & Quality Assurance

Plan operations based on critical process parameters.

Generate QC planning charts, operation instructions, and preventive schedules on this basis.

Institute training programs to enable production workers and supervisors to acquire these skills.

FIGURE 6

Detailed Description of Enhanced Quality Function Deployment (EQFD) phases

QFD Implementation Stage →	Awareness	Demonstrate Successful Case Studies	Company-Wide Training & Education	Adoption of Business Philosophy
	"Education" of Top Management Explain QFD Benefits • Quote Industry Anecdotes Compare with Existing Process	Select QFD Projects Train Team Members Select Strong Leader Ensure Information Availability Develop Complete Case Application Demonstrate Success	QFD Successes Teach QFD Philosophy Include Teamwork Train in QFD Support Tools	Manage Change Link to Strategy Establish Consistent Performance Systems Business Planning Concept • Evalute on Cost, Quality, Investment, Timing
Technology Adoption Stages	Identification	Transfer	Amplification	Acceptance

FIGURE 7

Stages in the Adoption of QFD

Stage	Expected Team Composition
Overall Product Planning	V.P. (Business Planning), V.P. (Product Development), V.P. (Marketing), V.P. (Sales), V.P. (Manufacturing), V.P. (Engineering, V.P. (Design), V.P. (Finance), V.P. (Procurement)
QFD Phase 1 (System Level)	Product Manager, Marketing Manager, Design Manager, Manufacturing Engineers, Sales & Service Engineers
Concept Selection	Marketing Manager, Design Engineering Specialists, Manufacturing Engineers, Suppliers, R&D
QFD Phase 2 (System Level)	Design & Component Specialists, Manufacturing Engineers, Field Sales & Service Engineers, Dealer-Level Data from Sales & Service, Marketing Manager, Finance (Product Costing)
Process Planning & Prototype Evaluation and QFD Phase 3	Design Engineers, Manufacturing Engineers, Material Handling Process Engineers, Process Planners, Suppliers, Equipment Suppliers, Purchasing Managers, Plant Manufacturing, Capacity Planners, Finance (Equipment & Process Costing)
QFD Phase 4	Design Engineers, Manufacturing Engineers, Process Engineers, Maintenance Engineers, Material Handling Engineers, Equipment Suppliers, Plant Manufacturing and Equipment Suppliers

FIGURE 8

Team Compositions at Different Stages of QFD

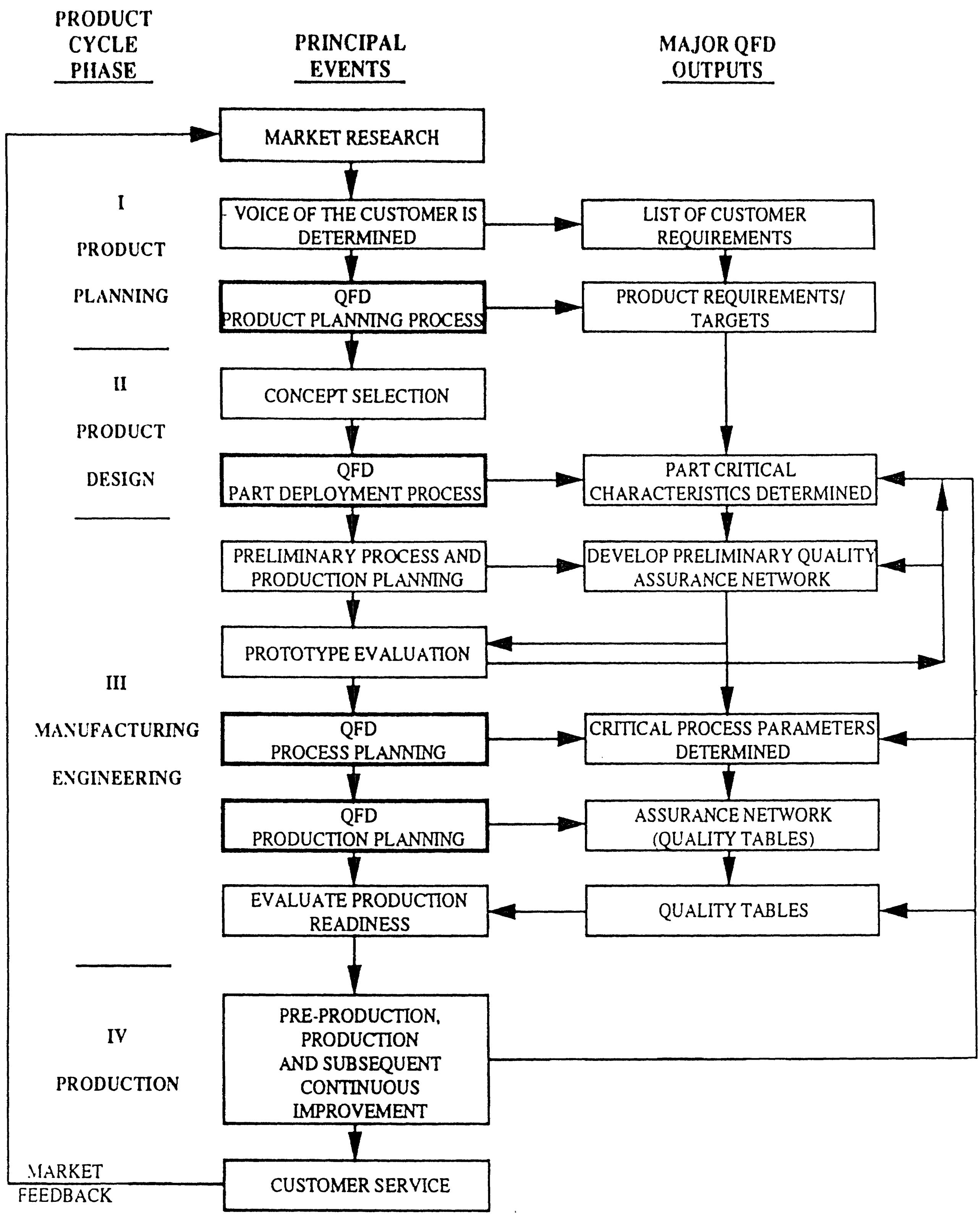

FIGURE 9A

QFD Flow Diagram--Basis for Framework for Evaluating Product & Project Performance
(Adapted from the QFD manual of the American Supplier Institute, 1989.)

QFD Phase	Major QFD Output	Product Evaluative Checks	Project Performance Checks
Product Planning	Product Requirements/ Targets	Do targets adequately meet customer requirements? Do these meet cost, quality and other objectives? Are these targets consistent with competing products?	Is project on time & budget? Is functional interaction successful? Man-hours?
Part Deployment	Part Critical Characteristics	Does the concept satisfy basic design requirements? Are the critical characteristics clearly specified? Are these achievable? Do the concepts take into account state-of-the-art and competitive capabilities?	Is project on time& budget? How many design changes have been made? Man-hours?
Process Planning	Critical Process Parameters	Do the process parameters meet part design requirements? Are they consistent with existing and forthcoming company technologies? Are design, manufacturing and plant engineers and managers in agreement?	Is project on time & budget? How many design changes have been made? Man-hours?
Production Planning	Quality Assurance Goals and Operating Instructions	Are production and quality targets reasonable? Are they consistent with equipment & staff capabilities, product budget targets, and customer needs?	Is project on time & budget? How many design changes have been made? How many process changes have been made? Man-hours?
		Is the part easily manufacturable? Are design and quality objectives being met?	Is project on time & budget? How many design changes were made? How many process changes? How much investment in equipment required? How much in excess of planned investment?

FIGURE 9B

Product & Project Evaluative Checks for Product Design Using QFD

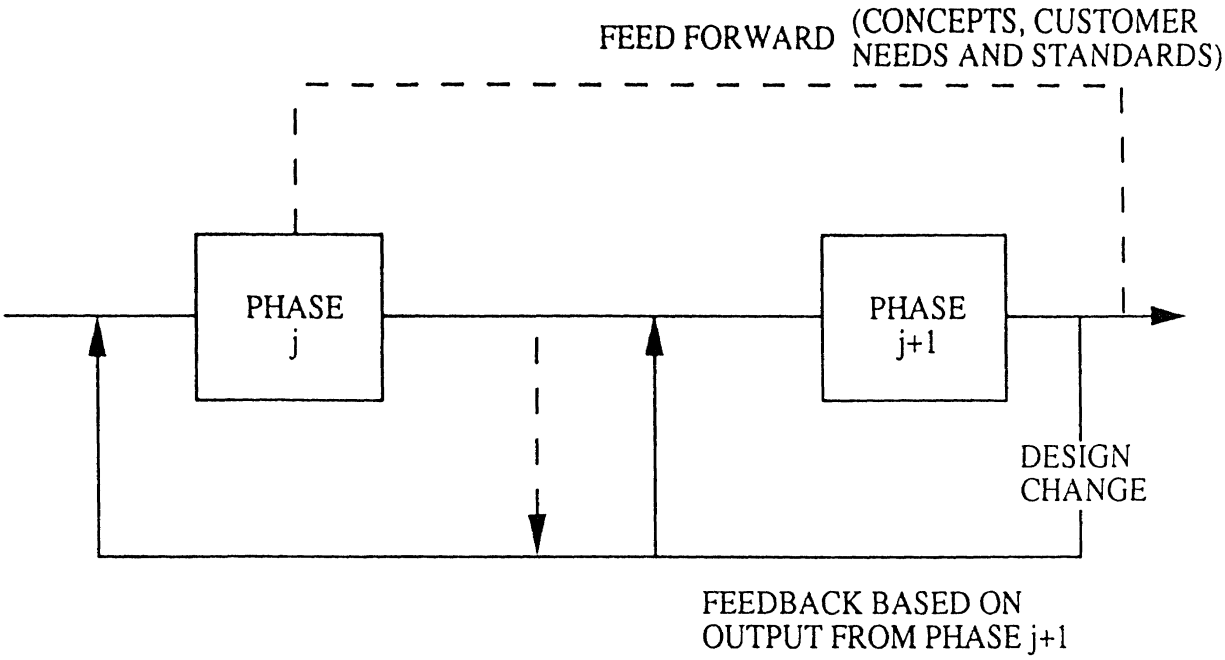

FIGURE 10

QFD Performance Evaluation System