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What and how about quality function deployment (QFD)

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Abstract

QFD is more a process than just a tool for product as well as production process development based on the concept of Company Wide Quality Control. Essential characteristics are: customer orientation, team approach and a way of concisely structuring communications and linking together information. The methodology is described to discuss experiences and some implementation problems.

Although first used by the Japanese, experiences from "Western" companies support the results of better products and production planning. Key factor for success is the Cross Functional Management approach.

Keywords: Quality function deployment methodology; Practice in the Netherlands; Implementation aspects; Dutch quality award

1. Introduction

Quality function deployment (QFD) is a customer-oriented approach to product innovation. It guides product managers and design teams through the conceptualization, creation and realization process of new products. QFD supports design teams to develop products on a structured way that relates market demand via engineering specifications to parts specifications and to production process variables and thus to production operations planning.

To discuss possible improvements of development processes by QFD we need to understand the philosophy and concepts that are the roots of this method. Approaches to quality based on the concept of Total Quality Control (TQC) as introduced by Feigenbaum [1] is fundamentally different from the Japanese TQC concept. In this vision TQC is "Company Wide Quality Control". It is more comprehensive and characterized by deploying customer desires horizontally and vertically throughout the organization (Japan Industrial Standard Z8101 – 1981).

The origins of the Japanese CWQC are the same concepts of statistical quality control (SQC) and TQC as they were brought over from the U.S. after World War II but they are deployed as means of securing quality accountability at each level in the organization [2] and combined with market orientation. The "voice of the customer" drives all activities.

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Often in many "Western" companies the executive's or engineer's voice dominates because there is still a strong influence of the ideas of scientific management. The separation of development and preparation from implementation and doing, as advocated by Taylor, brought us to organizations subdivided into more or less isolated functional departments, staffed with specialists for quality, cost and delivery (QCD-aspects), paying attention to output characteristics with separated performance objectives.

Because of that orientation the TQC concept is too often exclusively directed to the quality of product and service in a proper balance with costs and usually identified with manufacturing and assembly activities. US and European companies put a greater emphasis on problem solving and efficiency improvement during the implementation and production stage. In the CWQC approach more effort is put into designing quality at the development stage and the QCD aspects are managed by interrelation. Roughly, the differences concerning product development can be illustrated as depicted in Fig. 1.

The CWQC philosophy is characterized by customer orientation, cross functional management and process rather than product orientation. It refers to quality of management and the quality of work being done. Within that concept QFD provides a means of translating customer requirements for each stage of product development and production (i.e. marketing strategies, design, planning, process development, production control). It is a mechanism that serves as an "operational definition" of CWQC [3]. It means that although quality professionals are important participants to facilitate the QFD process, the marketing, development and manufacturing professionals play an even more vital role.

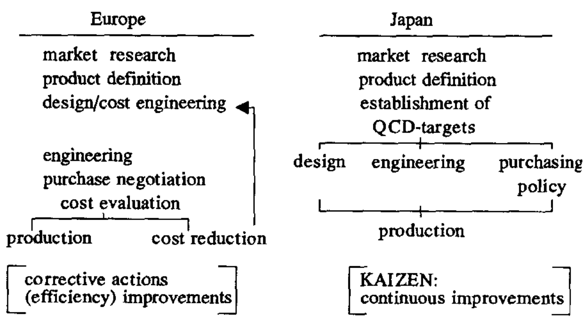

Fig. 1.

An organized QFD approach follows all the rules for project management, which means project definition, team selection and is not restricted to a single action within just one department. Teams should be cross-functional, expertise oriented and consisting of six to eight members of comparable peer levels.

QFD is a *process* that can help companies to make the key trade-offs between what the customer wants and what the company can afford to build. In essence, QFD encompasses same activities that people did before but it replaces erratic, intuitive decision making processes with a structured methodology that establishes all relevant information and experiences that are available throughout the organization. As such, QFD lays a basis for organizational learning.

In general, the product development process from customer-needs to manufacturing process operations, can be outlined by a step by step approach marking the points at which the requirements for intermediate results are established and go-or-no-go decisions can be made. Usually we can discern four phases:

Strategy and concept Definition → Product design → Process design → Manufacturing operations

In the strategy phase, product policy and determination of the customer will be established and the customer needs are translated into a product concept. The design requirements (WHAT's) serve as input to establish the component characteristics (HOW's) of the product design which on their turn serve to define the process plans and next the manufacturing process operations. Because of the complex relationships between the inputs and outputs, these relationships are mapped into matrices. The basic structure is depicted in the relationship matrix of Fig. 2.

The flexibility of the method of approach allows for adding any other information which may be

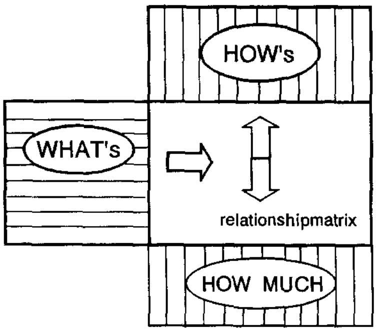

Fig. 2. Basic structure QFD.

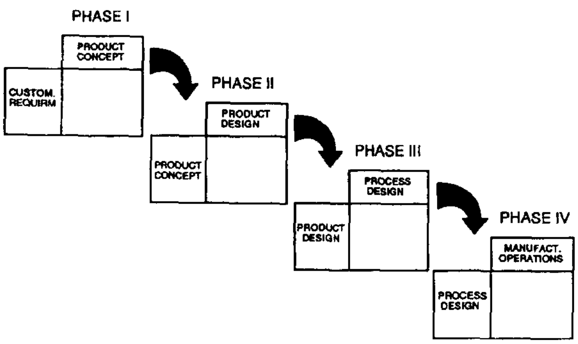

Fig. 3. Cascade of QFD charts.

useful to the decision making. When viewing a QFD-chart the first time, look for the What's - How's relationships. Each How will be appraised to set target goals or values, the How-Much's we want to achieve. These How-Much's should be measurable as much as possible.

Measurable items provide more opportunity for analysis and optimization. Using QFD charts the outlined development process can be depicted in four charts (Fig. 3) although in actual use as many levels of charts as necessary may be used.

Of all the steps in the total production development process, none deserves more and receives less attention than the definition of the right product for the right customer.

This first step is the most critical part of the process and it usually is the most difficult because it requires obtaining and expressing what the customer truly wants and not what we *think* he or she expects. The greatest gains of QFD will be realized when the "voice of the customer" gets to be deployed to the most detailed level of manufacturing operations. This means deploying all phases although it is possible to achieve substantial benefits by implementing QFD only in the first phase.

There are several useful extensions to the basic QFD-charts which greatly assist in the trade-off procedure to establish the values of the How-Much's. Decisions will be based on all the information normally available: business and engineering judgement as well as various analysis techniques. Once the first chart is completed, the downstream stages will be determined more and more by specific technological characteristics of a particular organization. So the most elaborated importance-rating systems and assessment tools are tailored to the first stage.

Here, in common with other generalized introductions to QFD, we will discuss some of the most important and well known expedients by building a "House of Quality" as it was named by Hauser and Clausing [4].

2. QFD methodology: "The House of Quality"

Starting a QFD-project, team members should reach agreement on issues as:

- which product or product characteristic are we going to focus on
- who do we consider as our customers
- which competing products will be used as a reference for product evaluation
- how does the QFD approach fit into product and process planning.

In the initial phase the scope of the project has to be established and should be communicated to and agreed upon by management. Management support is always very important because all available expertise as well as market information will be required. In order to turn a pilot project into a success it is critical to select an appropriate product to be employed (step 1; see Fig. 4). Try to find a project with broad appeal that may pique interest from several areas of the company. A first project should be simple, but not trivial, and present a real opportunity for improvement. Do not try to tackle your toughest problem in your first QFD-effort.

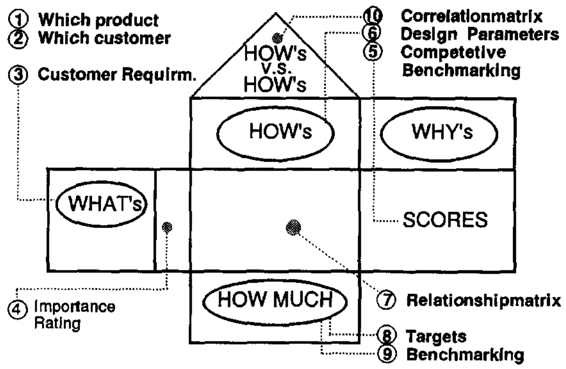

Fig. 4. The "House of Quality" showing the "rooms" of the various steps in the QFD process.

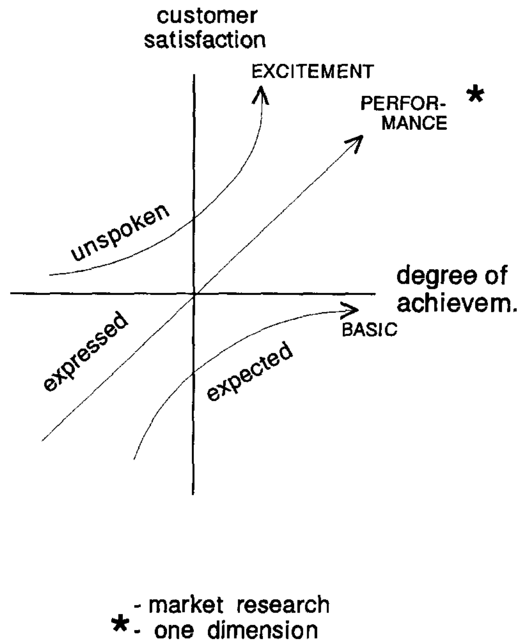

Fig. 5. The Kano model.

Step 2 deals with the kind of customer to focus on. Especially for consumer products a clear customer profile is needed. A good description includes the end-users but could also include profiles of persons or interest-groups who influence the purchase decisions, e.g., retailers, consumers' associations or public authorities (environmental regulations!). To collect information about customer requirements (step 3) various data collection methods are available.

For professional products it will be rather easy to ascertain requirements. Improving a current (consumer) product, than we already know a lot about the customers (market surveys, service calls, etc.). If we take a new product this will be more difficult. In that case a clear customer profile can help to estimate what is important, less important or not important. Sometimes a comparison between different target groups may help.

Asking consumers about their requirements, a distinction should be made between expressed requirements and implicit requirements. The Kano model [2] relates customer satisfaction to the degree to which product features (or requirements) are achieved (see Fig. 5).

The straight line represents *performance* features. We will be more satisfied if the performance exceeds our expectations and dissatisfied if they fall short. Generally, only these (mostly one-dimensional) requirements will be expressed by the customer when we ask for.

The implicit features fall into two groups: basic and excitement features. The basic features are *expected.* These include the fundamental functions which must be present along with safety and reliability considerations. Even if all of the basic features are implemented perfectly we would not achieve real customer satisfaction – we would only *eliminate dissatisfaction.*

The top curve represents the so-called *excitement* features. Sometimes these are seemingly minor items which the customers perceive as superior value. Focus on the excitement features as *sales points* can lead to a major competitive opportunity.

Requirements should be expressed in common parlance. So in the case of consumer products it is important to use expressions like: easy to carry, modern look, natural sound in stead of: xx kg; yy mm or zz Watts [5].

The "voice of the customer" needs to be worked out in order to gain a collective understanding. Using a function tree a rough requirement can be detailed into two or more levels (Fig. 6) to describe the "WHAT's" for the first QFD – chart.

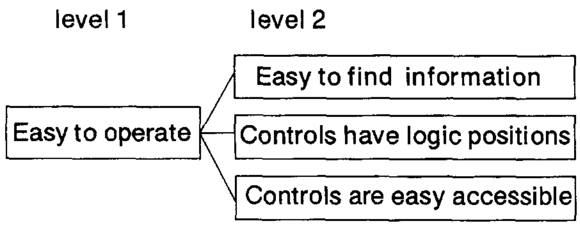

Fig. 6. Function tree with two levels.

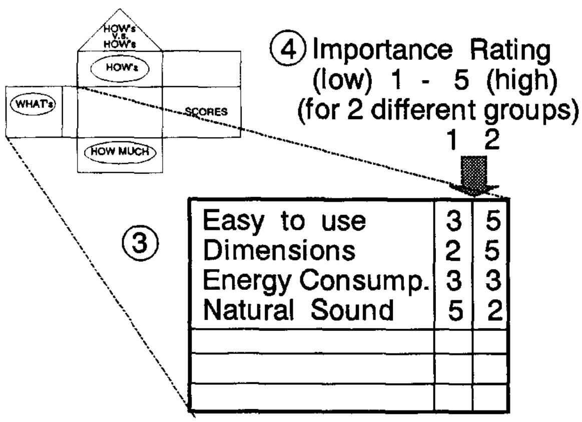

Fig. 7. What's list and importance rating.

The list of "WHAT's" should be sufficiently detailed to make judgements about the importance of each item to the customers on whom we focus. Depending on the target group the relative importance of the various requirements can be rated. This can be done using a scale from 1 (not very important) to 5 (very important) (step 4 see Fig. 7). In the case of obvious rating differences between the target groups, it is necessary to consider to develop tailored product types. (in Fig. 7, for example, a device for "sound freaks" or for "entertainment").

Customers choose between products of different brands. Therefore, it is of strategic importance to know how the products of our most important competitors match up to the customer requirements compared with our own product. Competitive benchmarking (step 5) answers the question "WHY" we should focus on which requirements and will allow a plan to be derived for improvement. This comparison is shown in Fig. 8.

The heart of the QFD methodology in the first phase is the generation of the design parameters: the "HOW's" list. The design requirements result from the translation of customer wishes into technical specifications (step 6). This list must be in balance with the available expertise and the given time and cost frames of the project. To depict the strength of the relationship between the What's and How's, symbols and/or an importance rating can be used for prioritizing efforts and making trade-off-decisions. Some commonly used symbols and weighing factors are shown in Fig. 9. The 9-3-1 weighing often achieves a good spread between important and less important items, although any weighing system which makes sense, may be used. Scientifically it will be always possible to improve the list but you should ask yourself whether additional information gathering will pay off in the project.

The design parameters refer to concrete observable characteristics and methods of measurement (see Fig. 10). From an organizational point of view sometimes it will be helpful if we arrange the characteristics under headings like: mechanical, electrical, software, etc.

The design parameters must reflect a valid measurement of customer requirements. As already said, there will be no one-to-one relationship and the interactions vary in intensity. The weighing and completion of the relation matrix (step 7) translate the project objectives into a technical priority-list.

This also permits us to *cross-check* our thinking. Blank rows or blank columns indicate places where our translation of What's into How's has been inadequate!

The operationalisations of How's are the HOW MUCH's. The How Much's should be measurable as much as possible. If How Much's are not measurable or nondescriptive, then we have not been detailed enough in our definition of the How's (another cross check of our thinking!).

We want HOW MUCH's for the following reasons:
- To determine priorities and directions for improvements of the How's (Sometimes an extra row to indicate this is added to the How-Much mapping).
- To provide an objective means of assuring that requirements have been met.

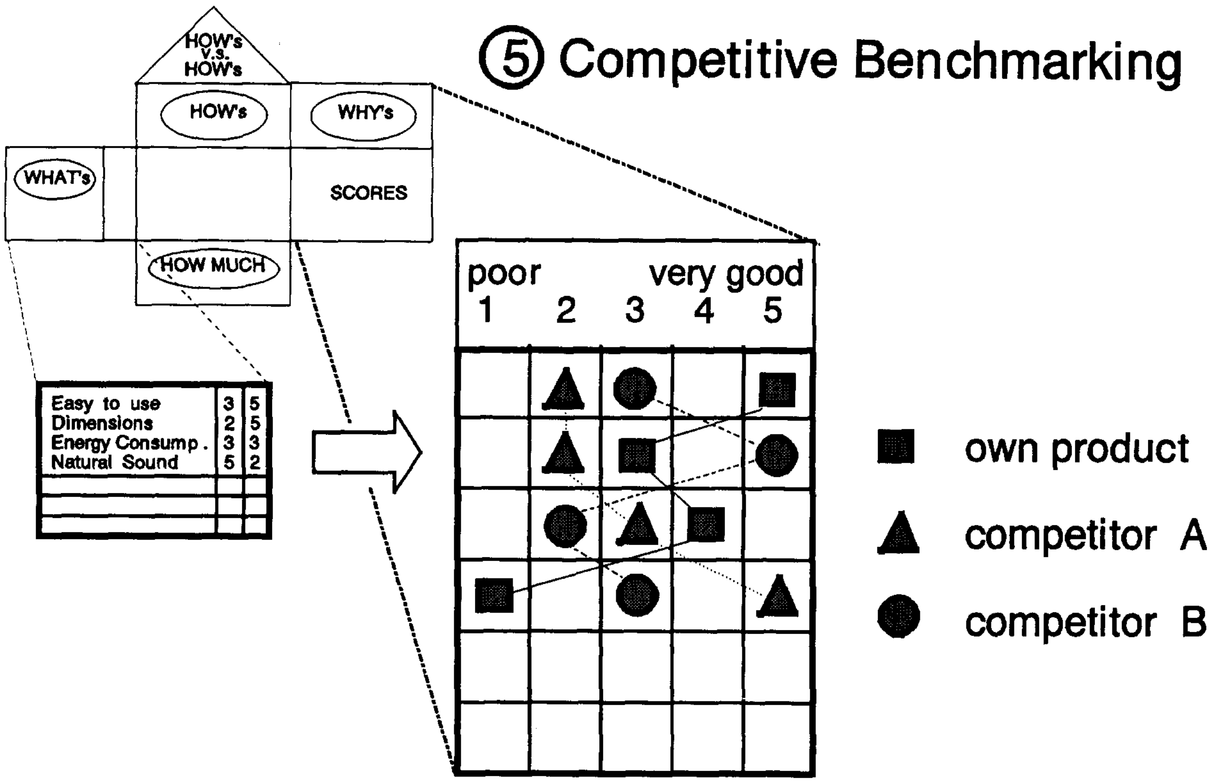

Fig. 8. Competetive benchmarking.

– To provide targets for further detailed development (step 8).

The targets are enumerated in the bottom part of the house.

To set the targets, it is quite common to perform a competitor's analysis on technical data. The benchmarking on technical performance (step 9) reveals our technical position with respect to our competitors. This kind of benchmarking provides a check for consistency of the relation matrix (step 7) and the competitive benchmarking data (step 5). For instance, a high score for customer requirement X should be reflected in high scores for design parameters which are strongly related with that requirement.

relationship	symbol	weighing factor
WEAK	Triangle	1
MEDIUM	Circle	3
STRONG	Dot	9

Fig. 9.

Mostly you will find interdependency between the design parameters. In the attic of the house supporting and conflicting design parameters are identified by a correlation matrix (step 10). Different degrees of interaction will again be represented by symbols. (see Fig. 11).

The assignment of positive or negative correlations are based on the influence of How's on achieving other How's regardless of the direction in which the How Much *values* move. Positive correlations are those in which one How supports another. The other way, negative correlations are those in which one How adversely affects the achievement of an-

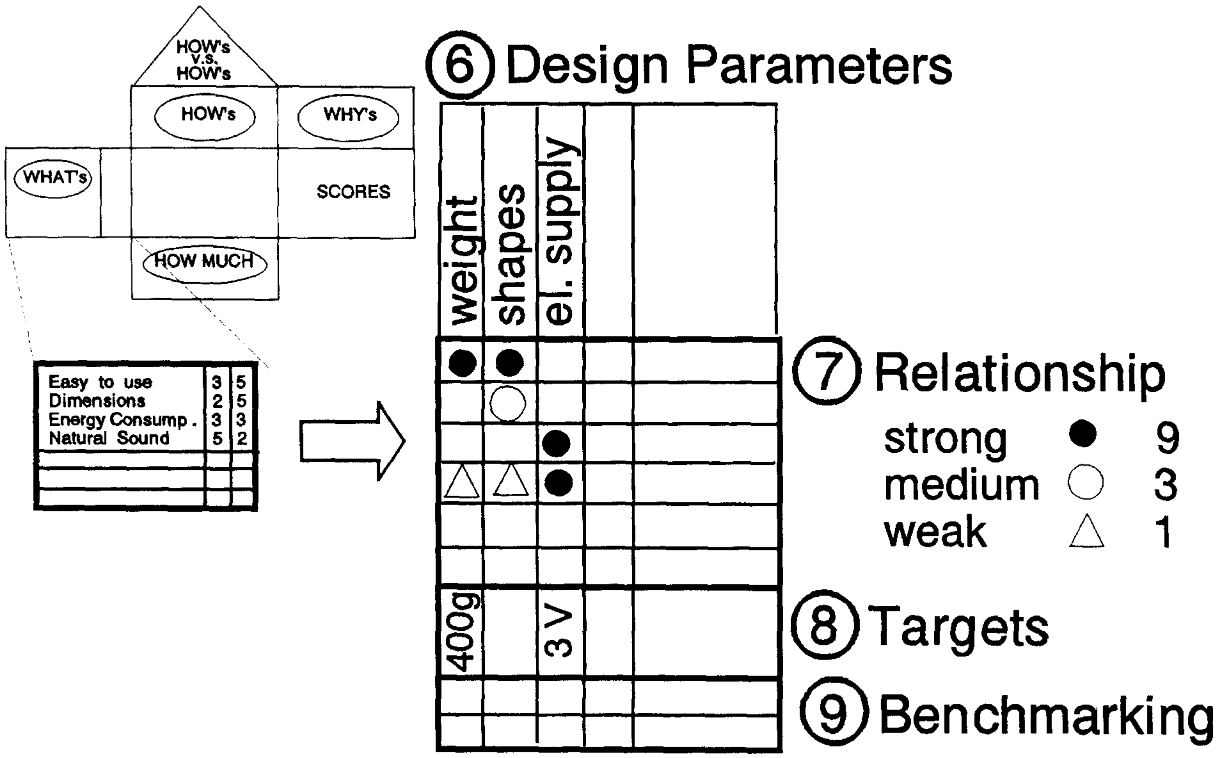

Fig. 10. Establishment of design parameters.

other How. These conflicts are extremely important as they represent conditions to direct trade-offs.

There are several useful extensions to the basic QFD charts which greatly enhance their usefulness [2, 6]. These provide some additional methodology to assist in the decision process. For instance, in the figures we made use of symbols. A popular method is the use of *importance rating*. For each cell, a relative weight is calculated by multiplying the ratings of the What's and the assigned weights to each relationship matrix symbol. Summing the weights for each column provides a relative importance of each How in achieving the collective What's (see Fig. 12).

However, it is important that we are *not* blindly driven by these numbers. These values as such have no direct meaning but rather must be interpreted by comparing the magnitudes to each other. We should question the relative values of the numbers in light of our judgement. Is it reasonable that the How valued at 90 is about ten times as important as the How valued at 9? And is it reasonable that How's with similar ratings are nearly equal in importance?

If our judgement is violated we should review the chart for possible errors. If the importance rating can be accepted and a trade-off decision is necessary between the How's with the 90 and 9 ratings, greater emphasis should be placed on the How with the 90 rating.

When the first phase has been completed, we have got a compilation of:

- customer requirements and their importance
- a competitive assessment of our product
- the relationships between customer requirement and design parameters
- priorities for improvement based on a cross functional approach
- a means to facilitate communication ensuring that the objective values and trade-off decisions are not "lost" and support the company's learning process.

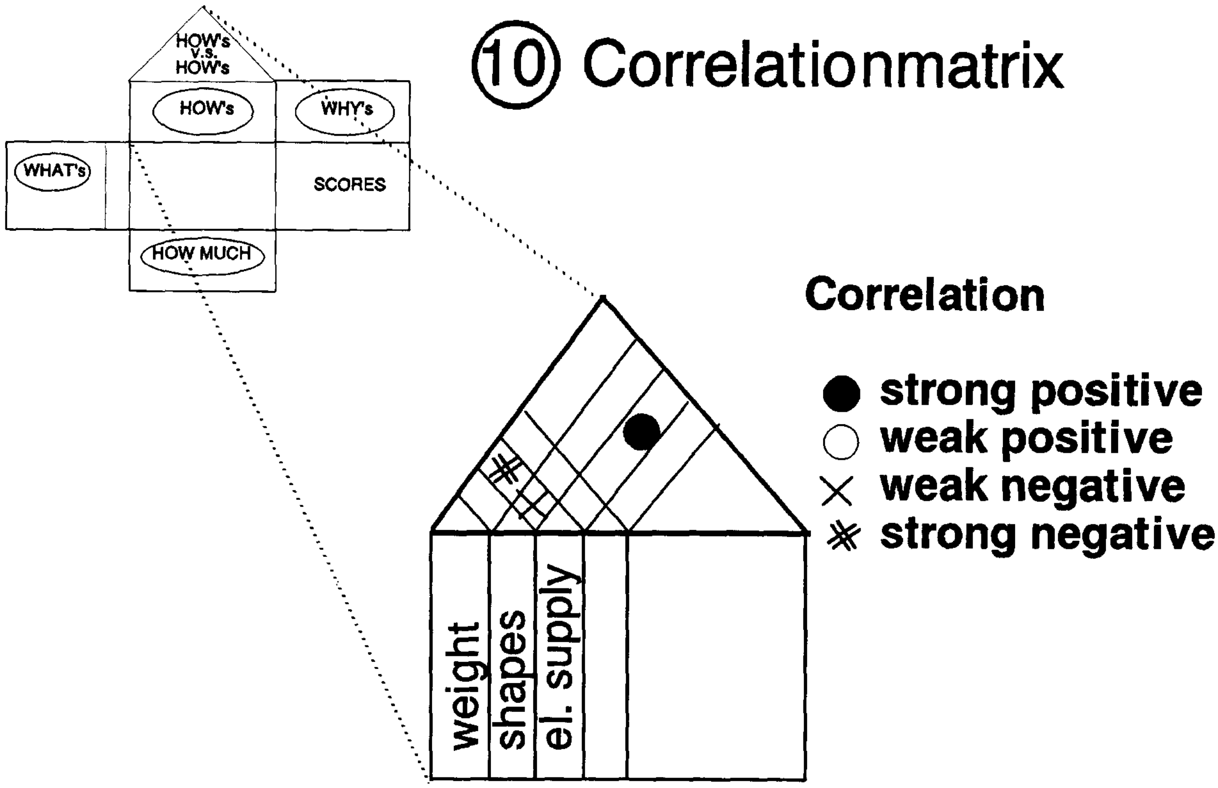

Fig. 11. Correlation matrix.

As already mentioned, in the next phase, the design requirements (HOW's) are carried on as WHAT's to the next chart to establish product or part characteristics. This is continued to define the process characteristics and subsequently manufacturing operations.

3. Practice

QFD, as a formalized approach started in 1972 when Yogi Akao introduced his "Quality tables" at the Kobe Shipyards. A survey of QFD usage conducted in 1986 among the larger member companies of JUSE showed that QFD had grown significantly. About 50% of the respondents reported that they were using QFD [11]. Frequently, Japanese success stories were attributed to a cultural difference. However, one must keep in mind that not *all* Japanese companies are equally successfull! Mainly the *best* ones demonstrate achievements with respect to their philosophies and methods. But what is more some of them demonstrate also to be successfull with their production plants in foreign countries.

In 1984 Clausing introduced the QFD approach in the United States to the Ford Motor Corporation. As a result of the article "The House of Quality" by Hauser and Clausing [4] the first case studies outside of Japan became known. The use of QFD in the United States is becomming quite popular. Each year various conferences bring together speakers to describe various analysis techniques and successful applications of QFD for a wide variety of industries.

Companies which used QFD reported the following benefits

- decreased start up problems
- competitive analysis became possible (improved market research)

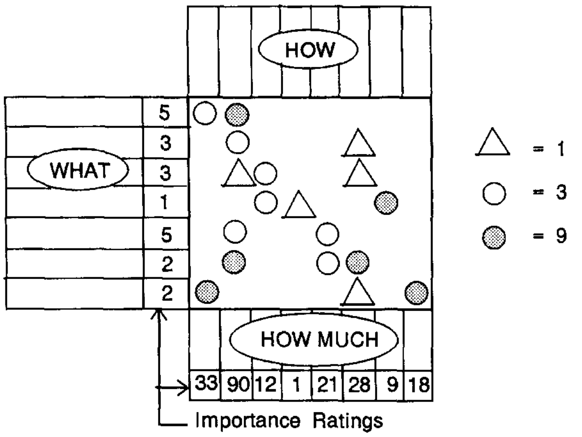

Fig. 12. Importance rating.

- control points clarified (reduced development time; better planning)
- effective communication between divisions (departments)
- design intent is carried through to manufacturing (Quality is built in "upstream").

However it is difficult to obtain specific case material to witness the improvements. Generally companies are very reluctant to broadcast their results because the results of a QFD process are highly confidential and of strategic value for the company.

One of the first applications of QFD in The Netherlands was within the Philips Corporation. Philips concentrated attention on QFD since 1986. The first successful application within the framework of the Quality Improvement Program was achieved in the Chungli monitors factory in Taiwan [5, 7]. Afterward (early 1989) it was introduced at the Eindhoven research and development department of high-end TV-tubes. This product is an extremely complex mixture of many interdependent technologies which resulted in a present House of Quality of approximately 150 times 120 positions. Filling in all the technologies (How's) and technical know-how in the chart provided a growing insight into the interactions between the weighed What's on one hand and the How's on the other. This knowledge facilitated decision-making and decreased dependence on "good feeling" for specification setting. This was especially useful for the experts. Each of whom who master a part of the technologies could not formerly make use of the "hidden" knowledge of his colleagues.

The use of QFD revealed that:
- the knowledge about customer requirements was insufficient
- data on competitors was handled incorrectly
- interdependences between technologies were only partly known.

The outcomes of the approach (first phase) are summarized/translated into one or more "scenario's" to support management decisions concerning strategies. The information is widely spread among specialists of the department so everybody can contribute to the process by his observations. It is difficult to express benefits in exact figures with respect to diminished lead times or costs. However it has become clear that top management get more insight in expected consequences (e.g., the need for adaptations or developments of production technologies) or not yet solved problems. Compared to the past they have become the "real" decisionmakers. Before sometimes solutions had to be selected on ad-hoc basis by lower management levels with restricted insight into possible consequences of their decisions.

Nowadays it is common policy to incorporate QFD into all development processes of this particular department. Most projects require product expertise from many different sections of the department. Therefore teams are cross functional groups of individuals representing appropriate disciplines like product planning, marketing, engineering and manufacturing. Sometimes, in the case of less complicated projects, the facilitator himself fills in the QFD-charts by consulting the specialists. The most important contribution of the facilitator is concentrating on the preparation of scenario's to communicate the QFD outcomes to people who are less familiar with the methodology.

An approach within "Van Doorne's Transmissie" (VDT) was quite out of the ordinary. Here the driving forces to apply QFD by some interested groups were very complex problems of process control. Because the product (a metal push belt for the automatic transmission) already existed they started to analyse the importance of and relations between process requirements and design variables (phase three). The results of this project persuaded quite a number of designers into the application of QFD in other areas of the development process and they will start to discuss the wants of the automotive industries with respect to the development of new generations of continuous variable transmissions.

The concepts of QFD are not restricted to the development of products or services. Sullivan [8] describes an approach for Policy Management in conceptual terms but he does not offer practical reference. Also in that field clear communication and customer orientation are fundamental for success. In an MSc-graduation project his ideas were worked out for the development and management of an annual policy declaration for a production plant of an international IC-manufacturer [9].

As far as I had contacts with Dutch QFD facilitators most of them reported technological improvements. Initial projects of QFD do not yield all expected benefits in one go. Early applications require more time and additional effort but results as knowledge transfer, better products and better understanding of the customer expectations are directly exploitable. Once a team has gained experience lead time and cost reduction as well as further reduction of product and production problems will be accumulated by fostering a better understanding of customers' requirements and what is needed to meet these requirements.

Most problems they had to untangle were related to organizational circumstances like project definition and project management as well as team selection and team building.

A critical factor concerning project definition is the "Voice of the Customer" (see Kano model) and what are the Critical Quality Characteristics [10].

With respect to project management and team selection, it can be mentioned that focus on the expertise is required but take care that the ranks of the team members should be about equal in order to avoid decisions being manipulated by ranking. Keep in mind that support from (top) management will be needed. It would be the best to have receptive, open-minded members on the team who are willing to challenge established practice.

4. Implementation

QFD is not a panacea for solving design problems nor for developing "perfect" products. The aim is improving the planning and control of the *development process*. This implies that the other processes of production are more or less under control. A company that still struggles with the quality performance at the expected and the specified level, has to stress basic quality techniques first and to change the culture towards more Total Quality Management. With respect to this the European Quality Award assessment model can be seen as a reference to derive criteria for production and development functions but also for the managerial functions. The Dutch Quality Award is copied from the European Award but for the interpretation of the established quality level, the path towards TQM is split up into five phases. Each level roughly corresponds with a score for the award:

- Phase I — Activity orientation: Problems are solved, but the process is not receiving attention. (0–200 pts)
- Phase II — Process orientation: Based upon process control, problems are solved in a systematic way. (200–400 pts)
- Phase III — System orientation: All functions of the organisation are controlled. Customer orientation is achieved including internal customers. Attention is paid to prevention of problems. (400–600 pts)
- Phase IV — Chain orientation with suppliers and customers: Optimal use of knowledge and capabilities for customer satisfaction. Cooperation is sought in order to minimise costs. (600–800 pts)
- Phase V — Total Quality Management: Philosophy and strategy are based upon a sense of responsibility within the society. (800–1000 pts)

The majority of "good" companies is at the level of approximately 400–500 pts which corresponds with the obtaining of an ISO certificate. Around 700 pts we find serious candidates for winning the award.

To implement QFD successfully a company should have reached roughly the upper level of phase II. This also can be an explanation that at present mostly the bigger firms benefit by the QFD method. Not only because they have the resources but probably more because they have already established a system (chain) orientation.

When an organisation is ready for QFD, there is the need for a good facilitator who knows the method very well and has also the social skills to build and to manage a team. Usually the first project will be more time consuming and appeal to open minded discussions. So look for people who has a positive attitude towards new approaches (early innovators).

5. Conclusion

It can be said that QFD is a synthesis of numerous methodologies originating from the USA (e.g., Value Engineering and market research) but they are perfected and integrated by the Japanese. Success stories from Japan are fairly known but do not forget that they have already a longstanding experience. Problems encountered by facilitators in the "West" concentrate on the realization of *Cross Functional Management*.

There is a wide variety of improvement tools that will enable companies to achieve high quality. Tools alone however cannot provide results on themselves. They must be developed to reflect the companies' culture and management vision. To implement QFD successfully a company has to be system oriented. QFD provides activities that bring together all required disciplines to work and plan the development efforts in a highly disciplined, communicative and effective manner. QFD as such is not a high technology rather it is a technology developed by *users* based on common sense and effective information transfer. Many Japanese and American companies have experienced QFD to be worth the effort.

When undertaking a project it is critical to take the time to *plan and organize* your efforts. An appropriate project needs to be selected with respect to its scope and objectives. Key factors for initial success are management support and the constitution of the team. The team members need to be given the time to establish its rules of operation and training requirements.

References

[1] Feigenbaum, A.V., 1961, 1983, 1986. Total Quality Control, McGraw-Hill, New York.

[2] Akao, Y., 1990. Quality Function Deployment, Integrating Customer Requirements into Product Design. Productivity Press, Cambridge, MA.

[3] Sullivan, L.P., 1986. Quality function deployment, Quality Progress. June, 39–50.

[4] Hauser, J.R. and Clausing, D., 1988. The House of Quality, Havard Bus. Rev. 63–73.

[5] Nijdam, L.M., 1990. Quality function deployment, in: Quality Matters, a publication of the CQB of Philips International, no. 21.

[6] King, R., 1989. Better Designs in Half the Time. Implementing Quality Function in America. 3rd ed. Goal/QPC, Methuen, MA.

[7] Rijsingen, P.H. and de Vries, R.F., 1991. Quality function deployment in picture tube production, in: Quality Matters, a publication of the CBQ of Philips International, no. 28.

[8] Sullivan, L.P., 1988. Policy management through quality function deployment, Quality Progress. June, 18–20.

[9] Philips, M., Sander, P. and Govers, C., 1994. Policy formulation by use of QFD techniques: a case study. Int. J. Quality Reliability Management, 11(5): 46–58.

[10] Govers, C.P.M., 1993. Quality of services "applicable to production?", Int. J. Prod. Econom., 30–31: 385–397.

[11] Goal/QPC, 1990. Quality Function Deployment: A process for translating customers' needs into a better product and profit, Research Report no. 89-10-02. Goal/QPC Methuen, MA.

[12] American Supplier Institute, 1987. Quality Function Deployment, Instruction Manual ASI, Dearborn, MI.