Quality Function Deployment: A Comprehensive Review

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Abstract

In this paper the capability of a customer focused quality engineering technique called "Quality Function Deployment (QFD)" have been reviewed. A comprehensive perspective of QFD and its potential areas for improvement have been provided, which could serve as an opportunity for further investigations. It has been found that comparing with other quality approaches, QFD is the most applicable technique for quality design and customer satisfaction subjects. QFD has been found to be superior, when suitably connected with other quality techniques.

Keywords:

QFD, Design, Benefits, Problem, Techniques, Improvement

Introduction

In order to build a quality product, customers' requirements (CR) have to be considered and addressed. From the designer's perspective, customer needs could seem to be vague, qualitative, incomplete and sometimes inconsistent. Customers only express *what* they want. Most likely these *what's* do not imply any "what exactly" in terms that make sense to designers, e.g. easy to use. Designers need to figure out *how* these *what's* can be satisfied by a product/service. Designers need detailed, technical-oriented requirements (*how's*) for design. There is an obvious gap between *what's* and *how's*. Customers "what's" are usually expressed in customers' own language without any implication of technology and implementations. These customers *what's* need to be translated into designers *how's*, which are quantitative, measurable and actionable technical specifications, so that they can be used by designers for design. *Hows* are designers understanding in technical terms of customers *what's*. Quality Function Deployment (QFD) is one of the techniques that can bridge the gap and help translate customers whats to designers hows (Menks et al., 2000). In the following, a comprehensive view of QFD is presented.

QFD terminology

Quality Function Deployment is derived from six Chinese characters with Japanese Kanji pronunciation (Figure 1): Hin Shitsu (quality), Ki Nou (function), Ten Kai (deployment). The Japanese characters for Hin Shitsu represent quality, features or attributes, Ki and No represent function or mechanization and Ten and Kai deployment, diffusion, development or evolution. Taken together, the Japanese characters mean "how do we understand the quality that our customers expect and make it happen in a dynamic way" (Cohen, 1995; Tottie and Lager, 1995;

Martins and Aspinwall, 2001; Chow-Chua and Komaran, 2002). Emphasis on quality plans is also the reason why it was named Quality Function Deployment by the Japanese (Akao, 1990; Leo Lo et al., 1994; Prasad, 2000). The translation is not exact or descriptive (e.g. hin shitsu is synonymous with qualities, not quality). It was therefore, just a matter of translation, but instead of using Attributes Function Development, say, the term Quality function Deployment evolved. However, the message is the same.

QFD has been defined in many different ways. QFD is a structured process, a visual language, and a set of inter-linked engineering and management charts, which uses the seven management (new) tools. It establishes customer value using the voice of the customer and transforms that value to design, production, and manufacturing process characteristics. The result is a systems engineering process, which prioritizes and links the product development process so that it assures product quality as defined by the customer/user (Dean, 1998). That is why the QFD process is often referred to as listening to the voice of the customer (Sower et al., 1999). QFD is also referred to as "house of quality (HOQ)". The reason for this is that matrixes in QFD fit together to form a house-shaped diagram (Bicheno, 1994; Kutucuoglu et al., 2001). QFD is oriented toward involving a team of people representing the various functional departments that have involvement in product development: marketing, design engineering, quality assurance, manufacturing/ manufacturing engineering, test engineering, finance, product support, etc. (Crow, 1996).

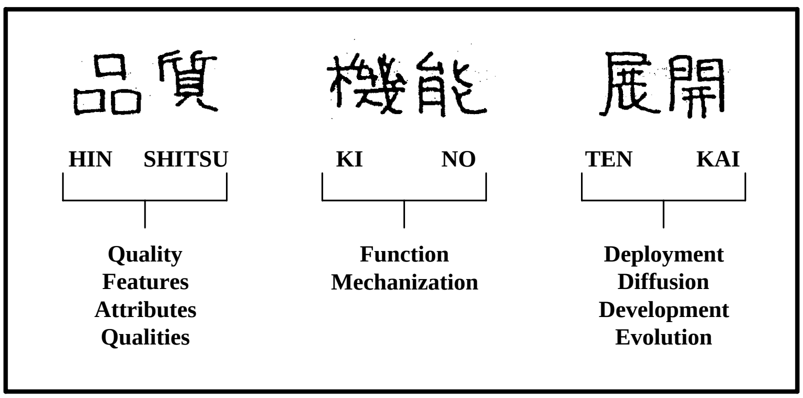

Figure 1. Translation of six Chinese characters for QFD (Cohen, 1995; Tottie and Lager, 1995; Garside and Appleton, 1996; Martins and Aspinwall, 2001; Chow-Chua and Komaran, 2002)

QFD is based on the concept of company wide quality control (CWQC). The CWQC philosophy is characterised 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 (Japan Industrial Standard Z8101, 1981). From that point of view, QFD becomes a management tool to model the dynamics of the design process (Govers, 2001). QFD is also known by the terms " Customer - driven engineering " and " Matrix product planning ". The whole concept is based on a sequence of operations to translate the voice of the customer into the final product or service (Smith and Angeli, 1995). Mallon and Mulligan (1993) defined QFD as a cross functional tool that assists technically oriented people, such as architects and engineers, to understand CR sufficiently, to develop priorities for these requirements that are customer oriented and technically correct. Mazur (1993), defined QFD as "a system and procedures to aid the plan and development of services and assure that they will meet or exceed customer expectations". Also, Akao (1990) defined it as "a method for developing a design quality aims at satisfying the customer and then translating the customer's demands into design targets and major quality assurance points to be used through out the production stage".

The term Quality Function Deployment is a poor translation of the original Japanese and rather than dwell on the meaning behind these particular words. In the light of the definitions, I describe QFD as: "Customer driven product development".

QFD and the House of quality (HoQ)

A four phases approach is accomplished by using a series of matrixes that guide the product team's activities by providing standard documentation during product and process development (Figure 2). Each phase has a matrix consisting of a vertical column of "Whats" and a horizontal row of "Hows". "Whats" are CR; "Hows" are ways of achieving them. At each stage, the "Hows" are carried to the next phase as "Whats".

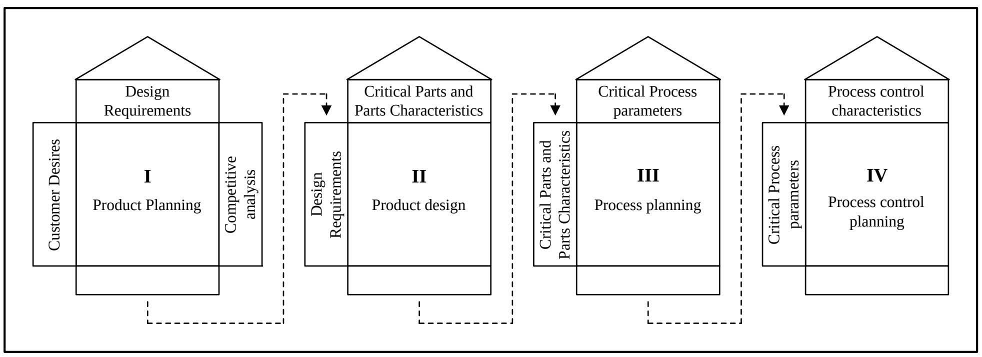

Figure 2. The four phases of traditional QFD (Cohen, 1995)

As a result, the House of Quality can be built in many shapes and forms. The general purpose of QFD model includes the components addressed in Figure 3.

Customers requirements (CR) - Also known as "Voice of Customer" or VoC, they are the "whats" the customers want from the product to be developed. They contain customers' wishes, expectations and requirements for the product.

Customer importance ratings - Once these "whats" are in place, the customer needs to provide numerical ratings to these "whats" items in terms of their importance to the customer. A numerical rating of 1 to 5 is often used, in which the number 5 represents the most important and 1 the least.

Customer market competitive evaluations - In this block, a comparison is made between a company's product/service and similar competitive products/services on the market by the customer. The comparison results will help the developer position the product on the market as well as find out how the customer is satisfied now. For each product, the customer gives 1 to 5 ratings against each CR, 5 being best satisfied and 1 the worst.

Technical specifications - They are the technical specifications that are to be built into a product with the intention to satisfy the CR. They are sometimes referred as "hows" because they are the answers to CR: how can the requirements be addressed or satisfied. They are the engineers' understanding in technical terms what customers really want. The technical specifications must be quantifiable or measurable so that they can be used for design.

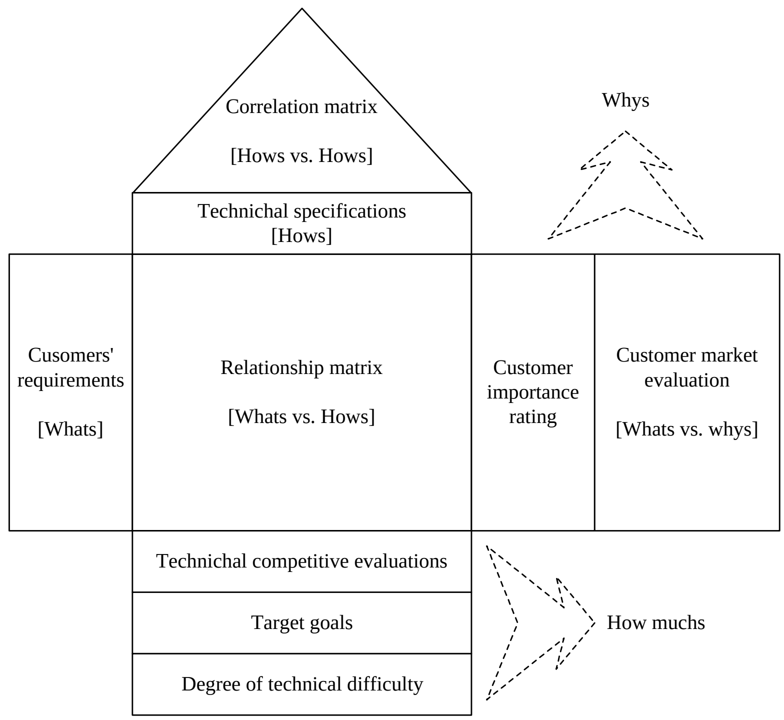

Figure 3. House of Quality (HoQ) in QFD (Menks et al, 2000)

Relationship matrix **-** Relationship matrix is used to maintain the relationship between CR and design requirements. In other words, the matrix corresponds to the "whats" vs. "hows". It is the center part of HoQ and must be completed by technical team. A weight of 1-3-9 or 1-3-5 is often used for internal representation of relationship, 1 being the weak and the biggest number being the strong relationship.

Correlation matrix **-** It is the triangular part in the HoQ (the "roof"). The correlation matrix is used to identify which "hows" items support one another and which are in conflict. Positive correlation help identify "hows" items that are closely related and avoid duplication of efforts. Negative correlation represents conditions that will probably require trade-offs. The positive and negative ratings are usually quantified using 2, 1, -1, and -2 ratings, with 2 being the two "hows" items are strongly supportive to each other and -2 being the conflicting. Sometimes only 1 and -1 are used.

Target goals **-** Completed by technical team, these are the "how muchs" of the technical "hows" items. They provide designers with specific technical guidance for what have to be achieved as well as objectively measuring the progress. The goals have to be quantified in order to be specific and measurable.

Technical difficulty assessment **-** Technical team conducts the assessment. It helps to establish the feasibility and realizability of each "hows" item. A 1 to 5 ratings are used to quantify technical difficulty with 5 being the most difficult and 1 being the easiest.

Technical competitive evaluation - It is used for comparing the new product with competitor's products to find out if these technical requirements are better or worse than competitors. Again, 1 to 5 ratings are used with 5 being the fully realized each particular "hows" item and 1 being the worst realized.

Overall importance ratings - This is the final step of finishing HoQ for phase 1. For each column, sum all the row numbers each of which is equal to the production of relationship rating and customer's important rating. The results help identify critical product requirements and assist in the trade-off decision making process.

QFD as a tool or as a system

Smith and Angeli (1995) determined three components of total quality management (TQM). In this type of classification, QFD was considered as a tool, or quality improvement tool. However, in the following it is specified that depend on its applications and due to its systematically process, QFD must be considered both as a tool and as a system. As QFD is a part of TQM, its influence actually permeates throughout the organization and synergistically encompasses many of the desired attributes, processes and tools of TQM (Appendix 1). Companies that have experiences in applying TQM, seems to employ QFD more easily than others.

Background of QFD

The concept of QFD was introduced in Japan by Yoji Akao in 1966 (Dean, 1998). QFD originated by professor Mizuno in 1972 to help design super tankers at Mitsubishi's Kobe shipyard site, Japan (Xie et al., 1998; Martins and Aspinwall, 2001). Toyota, the world's leading automobile manufacturer, and its suppliers then developed it. Since 1972, its use has grown very rapidly, simultaneously, it has realized a competitive advantage in quality cost and timing. In 1978, the first book on the subject was published in Japanese, which resulted in a large increase in the use of QFD in Japan. By 1986 a survey of larger number companies of the Union of Japanese Scientists and Engineers (JUSE) showed that over half of them were using QFD. Masao Kogure and Yoji Akao introduced QFD to the USA in the article "Quality function deployment and CWQC in Japan" which appeared in *Quality Progress* in the October issue of 1983 (Bier and Cornesky, 2001; Han et al., 2001). Among the first to experiment with QFD is Ford Motors, which used it to plan the transmission assembly process, and Chrysler to develop cars such as the Neon. Xerox and Ford initiated the use of QFD in the United States in 1986. 15 years after its debut in the USA, QFD has been widely applied in industries such as aerospace, software engineering, construction and marketing, and multinationals as diverse as IBM, HP, Gebneral Motors, AT&T, Digital Equipment, ITT, Baxter Healthcare, Texas Instruments, Miliken Textile, Black and Decker and Philips International have subscribed to its advantages (Prasad, 1998a). Early adopters of QFD in the US included 3M Company, AT&T, Baxter Healthcare, Budd, Chrysler, DEC, Ford Motor, General Motors, Goodyear, Hewlett-Packard, IBM, ITT, Kodak Eastman, Motorola, NASA, NCR, Polaroid, Procter and Gamble, and Xerox . To find more company names, the readers are referred to the annual US QFD Symposium transactions (http://www.qfdi.org/transact.htm). Also, QFD has been successfully used in many Japanese industries, such as agriculture systems, construction equipment, consumer electronics, home appliances, integrated circuits, software systems, steel, synthetic rubber, and textile (Chan and Wu, 2002). It is clear that most users in the US concentrate only on the first house of quality, whereas the use in Japan extends across the full scope of manufacturing through the use of the other matrixes of QFD. Use of QFD came to the UK and Europe in 1988/89 largely through the sister companies of those using it in the US automotive industry; but, the take up of QFD within the UK has been low. Discussion with companies in the UK indicates an inertia and similarity with the USA in that, in the main, only the first house of quality is used (Garside and Appleton, 1996).

Two organizations, the American Supplier institute (ASI), a non profit organization, and GOAL/QPC, a Massachusetts consulting firm, have publicised and developed the concept in the United States (Evans and Lindsay, 1993; Vairaktarakis, 1999). Extensive training was underway in the US by 1986 and pioneering companies such as Ford were lunching their first projects. Many Japanese, American, and European companies have adopted QFD for some or all of their product/ service development. A recent large-scale study on global manufacturing indicates that QFD is among "the 10 action programs that received the most attention and the top 10 programs that had the greatest pay-offs" (Chan and Wu, 1998; Shin and Kim, 2000)

Specifically, Zultner (1994) classified the applications of QFD in three groups as: hardware, software and service (Figure 4). Also, Hunt (1998) emphasised that the general applicability of QFD is not only in the traditional area of product, service, and software, but also to the area of strategy development and deployment.

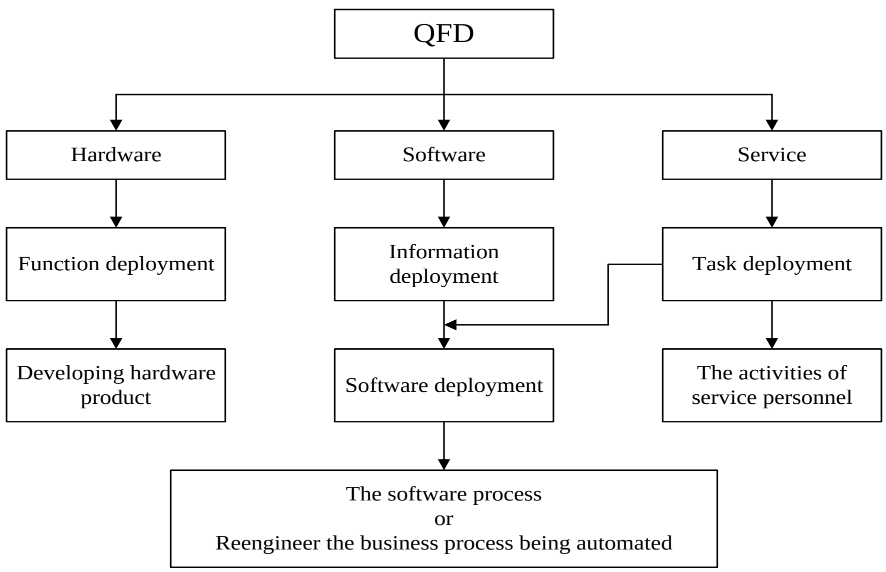

Figure 4. A classification for the applications of QFD (Zultner, 1994)

Cristiano et al. (2000) conducted a survey about the QFD application and use in America and Japan (Figure 5 and Appendix 2). They had expected QFD to be more widely and effectively used in Japanese companies than in the U.S companies; but according to those Appendixes, the results contradicted those expectations. The U.S companies used QFD to a greater extent and reported deriving more significant product and process improvements. Also, Appendix 3 presents a brief history of QFD, from 1968 to 1994, in North America and Japan.

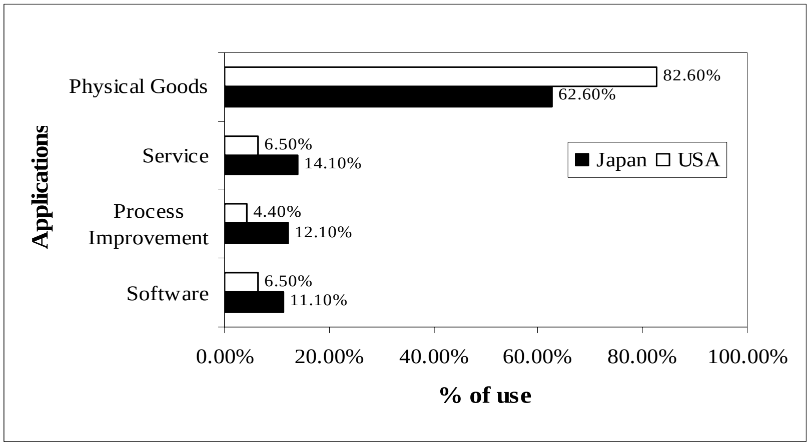

Figure 5. QFD application and use (Cristiano et al., 2000)

History of combining QFD with other techniques

Combining QFD with other techniques gives a credit to the use of QFD as a systematic mechanism that is helpful in getting the greatest return on organizations' investments on quality improvement. QFD is an appropriate framework for integrating other principles and methods, where the voice of the customer selectively guides the application of efforts to eliminate waste and foster continuous improvement (Fortuna, 1988). Because of the flexibility of QFD, it has been combined with other techniques and tools to develop its abilities. An example of QFD combination with other techniques is given in Appendix 4.

It should be borne in mind that QFD, and any other quality tool or technique, should not normally be used in isolation, but should be an integral part of the continuous improvement process. QFD is a planning tool and organizes data in a logical and systematic way, but it is rather a qualitative method. The union of QFD with quantitative methods will yield even greater benefits from its applications (Howell, 2000).

History of modification and extension of QFD techniques

QFD has a high potential of redesign and development. These make it relevant to play a major role as the central part of the proposed methodology. A summary of the modifications and extensions of QFD is presented in Appendix 5. As it is illustrated in Appendix 4 and 5, QFD seems to be a flexible technique and it could provide great benefits, if considered as the central point of the integration of advanced quality engineering techniques.

Countries experienced QFD

According to Appendix 6 and the literature, it seems that USA, Europe and Asia share more in QFD applications than other parts of the world.

QFD publications

Many countries have published work on QFD over the years. Much of the work done on QFD goes unnoticed because of the lack of publications or the fear of companies admitting to their competitors that they use such tool. Some work is published in native languages, unknown on an international level. Since a lot of companies are reluctant to their most important breakthroughs, or their means achieving them, it is difficult to obtain data on which companies are using QFD. The first international symposium was held in 1989 in Novi, Michigan, USA. Today there are regular events in other countries as well as "the Annual International Symposium" usually held in Michigan, USA. A comparison of publications about other quality methods was performed, which extended from 1989 to 1998 in an attempt to demonstrate that QFD is under utilised. Appendix 7 shows how few publications there are on QFD (5%), compared to other quality methods, techniques and standards such as Taguchi method (13%), ISO 9000 (15%) and SPC (27%), using information compiled from the Bath Information Data Services (BIDS) and Edinburgh Engineering Virtual Library (EEVL).

Functional fields of QFD

There is no definite boundary for QFD's potential fields of applications. The distribution of some of existing resources is presented in Appendix 8. As it is shown, customer needs analysis, takes the most participation, comparing with other fundamental fields of QFD. This is due to the importance of customers' needs in the first HoQ in the QFD methodology.

Applied industries of QFD

The distribution of some of the resources is presented in Figure 6. As it is shown, comparing with other published issues on applied industries of QFD, resources on manufacturing and services have the majority.

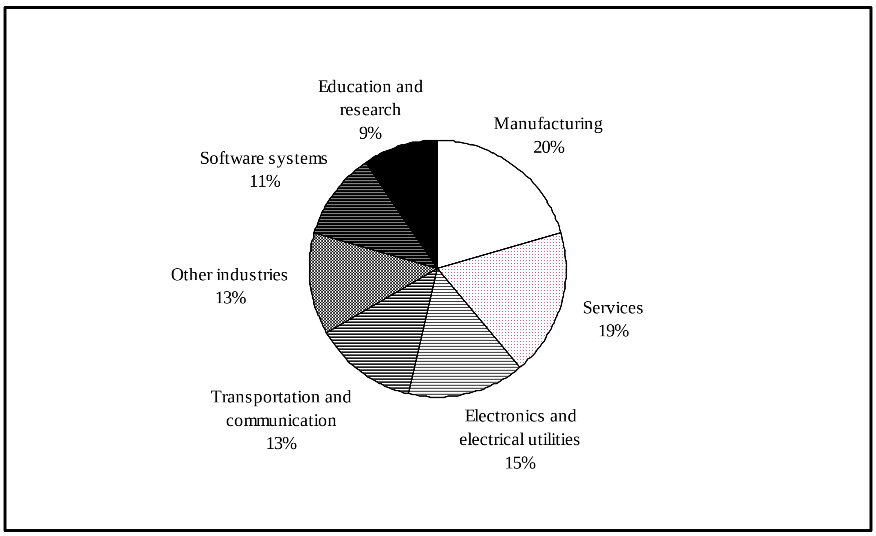

Figure 6. % of publications of Applied industries of QFD (Chan and Wu, 2002)

Methodological development of QFD

As it is illustrated in Appendix 9, methodological development of QFD takes 36% of all the QFD issues and the extensions and implementation issues of QFD are the most published issues (45%), comparing with other issues on methodological development of QFD. In other words, the extensions and implementation issues of QFD, form about 16% of total issues of QFD.

QFD objectives

Table 1 summarises some of the important objectives of QFD. It is important to note that a design project can be considered as a mixture of all objectives. While some trading off is often unavoidable, the way to achieve an outstanding product is to seek to optimize all elements.

Table 1. Some of the important objectives of QFD

Resource	QFD objectives
Vonderembse and Raghunathan (1997)	To drive long-term improvements in the way new products are developed in order to create value for customers
Kathawala and Motwani (1994); Zairi (1995)	(1) Identify the customer (2) Determine what the customer wants (3) Provide a way to meet the customer's desires
Franceschini and Rossetto (1995)	(1) Definition of the product characteristics, which meet the real needs of the customers. (2) Gathering of all necessary information to set up the design of a product or a service, without neglecting any point of view. (3) Supplying a support to competitive benchmarking. (4) Preservation of coherence between the planning and manufacturing processes of a product. (5) Provision of an audit trail from the manufacturing floor back to customer demands. (6) Auto documenting the project during its evolution.
Jagdev et al., 1997	(1) Identify current performance measures that are closely linked to CR. (2) Identify current performance measures that are redundant. (3) Identify new customer oriented performance measures that are required. (4) Identify conflicts associated with different performance measures. (5) Identify target values for customer oriented performance measures. (6) Assess the degree of difficulty of achieving the target value(s) for specific performance measures.

QFD as a quality technique for design

QFD is one of those quality techniques, which can be applied for detecting the defects at the design phase of products/services.

A product undergoes a number of stages before it reaches the market for end users. Figure 7 shows the quality management approaches, and the techniques associated with the stages of product development. Generally speaking, all three approaches are important to maintain and improve quality. However, it is the degree of emphasis among approaches that would make all the difference. Today, good quality is considered more a function of good design than of process control. There is evidence that, by better understanding customer needs and carefully incorporating these needs into product design, companies can reduce significantly the number of design changes in the innovation process, and reduce start-up costs and lead times for product development. The techniques must be considered as an integral part of the total quality system. In this point of view, QFD can be chosen as a good quality technique for improving quality at the off-line stage, or quality by design approach.

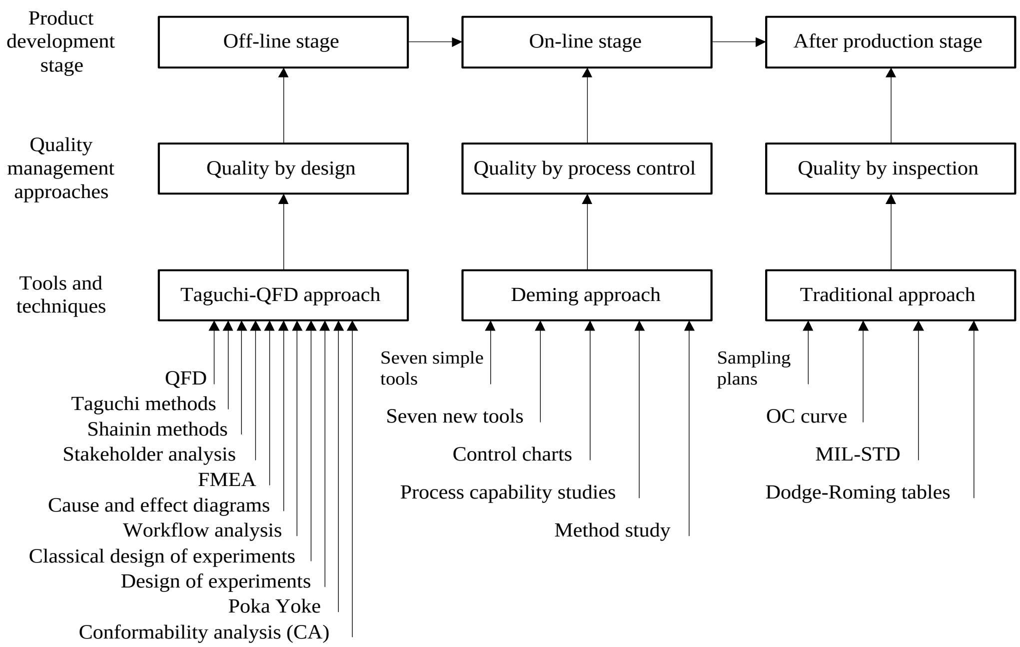

Figure 7. The product development stages, quality management approaches and techniques (Ur Rahman, 1995; Field and Swift, 1996)

Benefits of QFD

Hauser and Clausing (1996) compared startup and preproduction costs at Toyota auto body in 1977, before QFD, to those costs in 1984, when QFD was well under way. HoQ meetings early on reduced costs by more than 60 %. Appendix 10, rainforces this evidence by comparing the number of design changes at a Japanese auto manufacturer using QFD with changes at a US automaker. Also, Hauser and Clausing considered the difference between applying QFD in Japanies companies and not applying QFD in U.S. companies (Appendix 10). As the Appendix shows, Japanese automaker with QFD made fewer changes than U.S. company without QFD. Some benefits of QFD are illustrated in Table 2.

Problems and mistakes during the use of QFD

QFD is not always easy to implement, and companies have faced problems using QFD, particularly in large, complex systems (Harding et al., 2001). Govers (2001) emphasised that "QFD is not just a tool but has to become a way of management". He also categorized problems of QFD in three groups as: methodological problems, organizational problems and Problems concerning product policy. Table 3, presents some regular problems of QFD.

Table 2. Major benefits of QFD

Benefits of QFD	Source
Major reduction in development time and costs, shorter design cycles and changes. Significantly reduced start up problems, times, and costs.	Ferguson (1990); Stocker (1991); Stauss (1993); Kathawala and Motwani (1994); Dahlgaard and Kanji (1994); Kenny (1988); Markland et al. (1995,1998); Hales (1995); Bendell (1993); Bouchereau and Rowlands (1999, 2000a); Fortuna (1988); Lockamy and Khurana (1995); Curry and Herbert (1998); Zairi (1995); Franceschini and Rossetto (1995); Howell (2000)
Leads to truly satisfied and delighted customers.	Emer and Kniper (1998); Kathawala and Motwani (1994); Kenny (1988); Lim and Tang (2000); Stauss (1993); Howell (2000); Stocker (1991); O'Neal and Lafief (1992); Markland et al. (1995, 1998); Hales (1995); Bendell (1993); Bouchereau and Rowlands (1999, 2000a); Lockamy and Khurana (1995); Curry and Herbert (1998); Zairi (1995); Franceschini and Rossetto (1995)
Improved communication within the organization. Brings together multi-functional teams, and encourages teamwork and participation.	Designing for customer satisfaction (1994); Kathawala and Motwani (1994); Stauss (1993); Dahlgaard and Kanji (1994); Stocker (1991); Markland et al. (1995,1998); O'Neal and Lafief (1992); Hales (1995); Bouchereau and Rowlands (1999, 2000a); Lockamy and Khurana (1995); Zairi (1995)
The quality and productivity of service will become more precise in a continual improvement process, and the company can reach world class.	Designing for customer satisfaction (1994); Kaneko (1991); Ermer and Kniper (1998); Howell (2000); Stocker (1991); Markland et al. (1995,1998); O'Neal and Lafief (1992); Hales (1995); Bendell (1993); Fortuna (1988); Zairi (1995); Franceschini and Rossetto (1995)
QFD clarifies customer priorities for competitive advantage. Marketing advantage through increased market acceptability – leading to increased market share and better reaction to marketing opportunities.	Ferguson (1990); Lim and Tang (2000); Dahlgaard and Kanji (1994); Stocker (1991); Markland et al. (1995,1998); Hales (1995); Bendell (1993); Fortuna (1988); Lockamy and Khurana (1995); Curry and Herbert (1998); Zairi (1995)
Enables one to focus proactively on CR early in the design stage. Critical items identified for parameter design, and product planning is much easier to carry out. Also, ensure consistency between the planning and the production process.	Ferguson (1990); Emer and Kniper (1998); Kathawala and Motwani (1994); Stauss (1993); Dahlgaard and Kanji (1994); Stauss (1993); O'Neal and Lafief (1992); Zairi (1995)
Brings together large amount of verbal data, organizes data in a logical way, and producing better data for refining the design of future products and services.	Emer and Kniper (1998); Stocker (1991); Markland et al. (1998); Bouchereau and Rowlands (1999, 2000a); Zairi (1995)

Table 3. Some regular problems of QFD

Problems of QFD	Source
If all relational matrixes combined into a single deployment, the size of each of the combined relational matrixes would be very large. Completing QFD late, does not let the changes be implemented. It takes a long time to develop a QFD chart fully.	Kathawala and Motwani (1994); Dahlgaard and Kanji (1994); Prasad (2000); Zairi (1995); Dale et al. (1998); Bouchereau and Rowlands (1999, 2000a); Designing for customer satisfaction (1994)
QFD is a qualitative method. Due to the ambiguity in the voice of the customer, many of the answers that customers give are difficult to categorize as demands.	Dahlgaard and Kanji (1994); Bouchereau and Rowlands (1999, 2000a); Designing for customer satisfaction (1994)
It can be difficult to determine the connection between customer demands and technical properties. Organizations do not extend the use of QFD past the product planning stage.	Dahlgaard and Kanji (1994); Dale et al. (1998); Bouchereau and Rowlands (1999, 2000a)
QFD is not appropriate for all applications. For example, in the automotive industry there are only a limited number of potential customers; the customer identifies their needs and the supplier acts to satisfy them. For a product of limited complexity and a small supplier base, the effort required to complete a thorough QFD analysis might be justified by customers. Setting target values in the HoQ is imprecise. Strengths between relationships are ill-defined.	Dale et al. (1998); Bouchereau and Rowlands (1999, 2000a)

Conclusions

In this paper, an attempt was made to demonstrate the capabilities and weaknesses of QFD which has been regarded as one of the most important advanced quality engineering techniques. QFD has been found to have some considerable problems, most of which seem to affect adversely its employment. Examples of some of the most important ones are: ambiguity in the voice of the customer (VoC), managing large HoQ and conflicts between Customers' requirements (CR). In spite of the above problems, there are however a wide range of benefits and advantages associated with using such a customer satisfaction quality design technique, which make it beneficial to designing quality. QFD is a quality design and improvement technique and relatively is closer to the customers than other techniques. Also, QFD can serve as a flexible framework, which can be modified, extended, and be combined with other quality design and improvement techniques. There are still not enough publications about the use of QFD in service areas. However, comparing with other quality design techniques, QFD has the potential to be the most suitable technique for designing quality from customers' point of view. It is believed that the present investigation will provide some good research opportunities; For instance, emphasising on enhancing QFD's capabilities and improving the associated problems with this technique. The flexibility of QFD has facilitated its integration with other advanced quality engineering techniques. However, the following recommendations are made to enhance the capabilities of QFD:

1) More care should be taken to the beginning phases of QFD process (e.g. first house of quality) and new models should be proposed to improve the evaluation of the input data (e.g. customers' requirements), before entering into other HoQs.
2) The effectiveness of QFD should be improved through its integration with other quality engineering techniques which could improve the functioning of traditional QFD at its early stages with respect to: competitive analysis, correlation matrixes, determining critical items, number of phases needed and components of its phases.
3) Enhancements must be designed to take place, with a focus on current problems associated with QFD (e.g. ambiguity in VoC, managing large HoQ and conflicts between CR).

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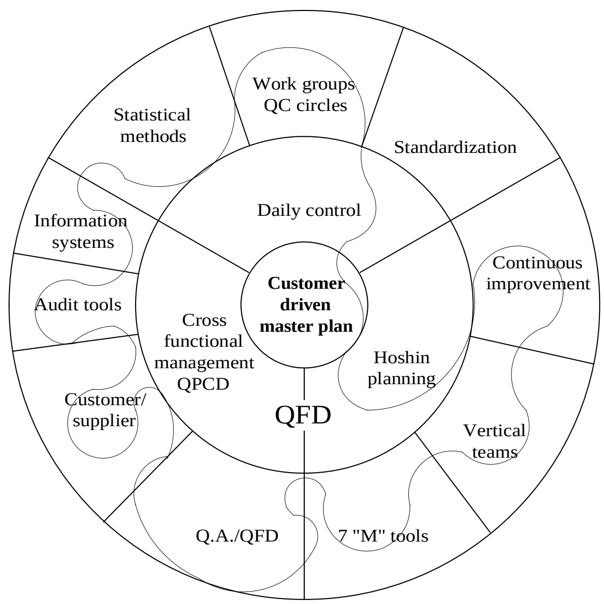
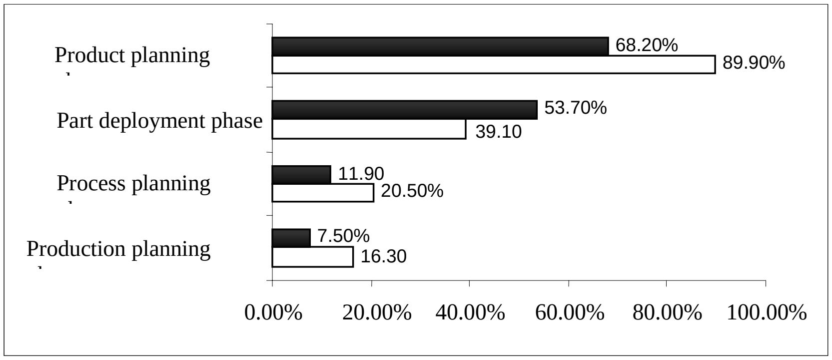
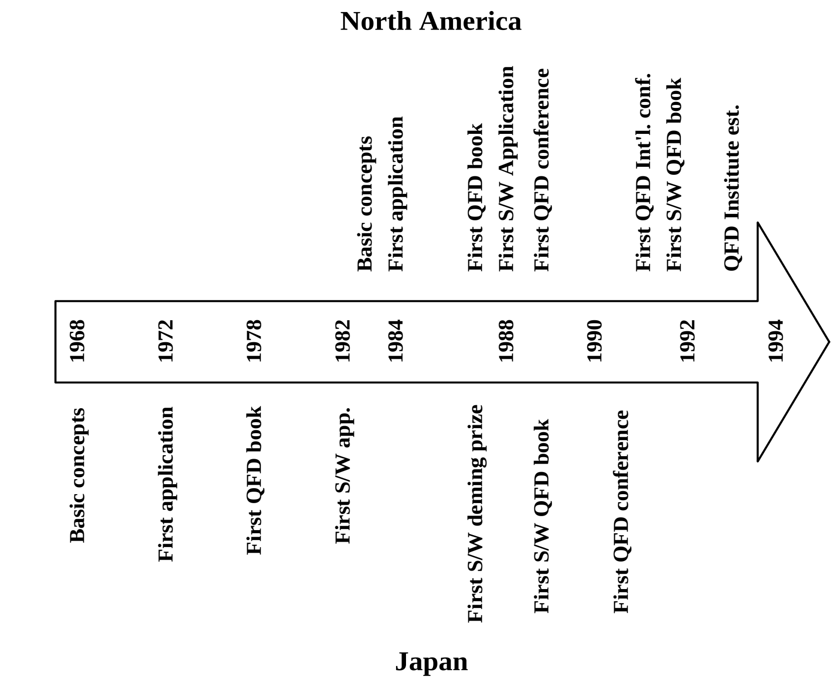


Appendix 1. QFD inherently incorporates and orchestrates many TQM processes/tools for improving business operations (Cheng Lim et al., 1999)



Appendix 2. Advanced phases of quality deployment used in Japan and USA
(Cristiano et al., 2000)



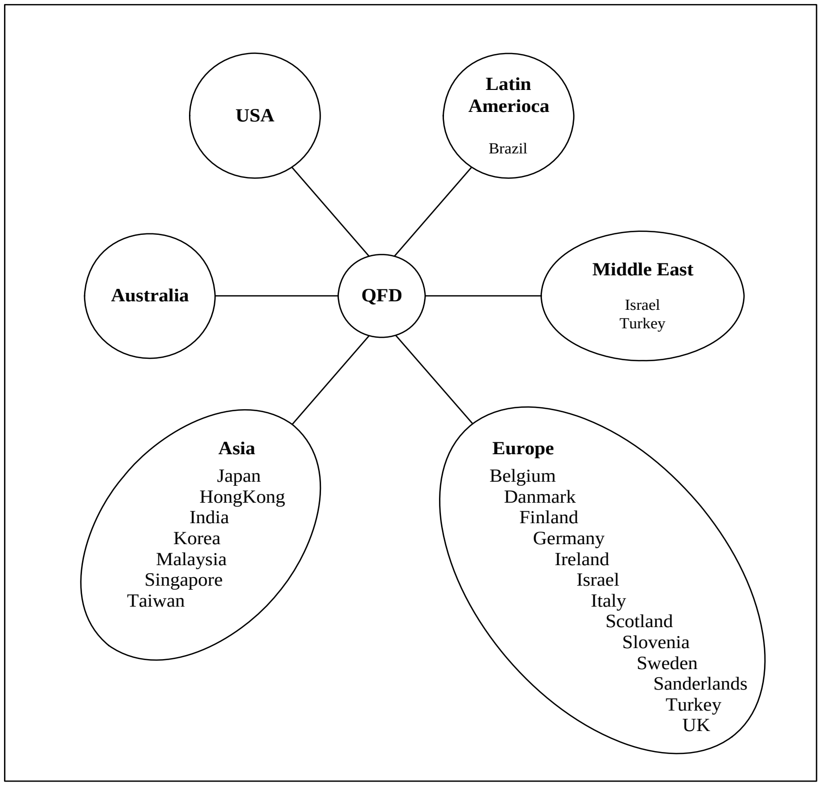
Appendix 3. History of QFD: a comparison between North America and Japan
(Zultner, 1994)

Technique	Resource
AHP and 0-1 integer programming	Partovi (1999)
AHP and Benchmarking	Partovi (2001)
Concurrent engineering techniques	Scheurell (1992) & Prasad (1996)
Corporate requirements	Gershenson and Stuffer (1999)
Cost, Reliability and Technology	Akao et al. (1983)
Data envelopment analysis	Kauffmann et al. (2000)
Design cost	Bode and Fung (1998)
Design function deployment	Evbuomwan et. Al. (1994)
Design structure matrix	Harr et. Al. (1993)
FMEA	Ginn et al. (1998)
Fuzzy sets	Masud & Dean (1993)
Hierarchical framework	Han et al. (2001)
Hoshin Kanri	Pun et al. (2000)
Kano's model	Matzler and Hinterhuber (1998), Shen et al. (2000), Tan and Shen (2000)
Life cycle costing/ assessment (Green QFD)	Zhang et al. (1999)
Multiattribute design optimization	Locascio & Thurston (1993)
Marketing	O'Neal and Lafief (1992)
Non linear programming techniques	Prasad (1993)
Object oriented software design methodologies	Lamina (1995)
Process management	Conti (1989)
Pugh's concept	Pugh (1991)
Reliability	Schubert (1989)
Reusability	Witter et al. (1995)
S-Model	Cook and Wu (2001)
Software engineering	Betts (1990)
Taguchi method	Bouchereau and Rowlands (2000a), Taguchi (1987) ; Taguchi & Clausing (1990)
Target costing	Brusch et al. (2001), Hales and Staley (1995)
Value engineering and Value graph techniques	Prasad (1998b)

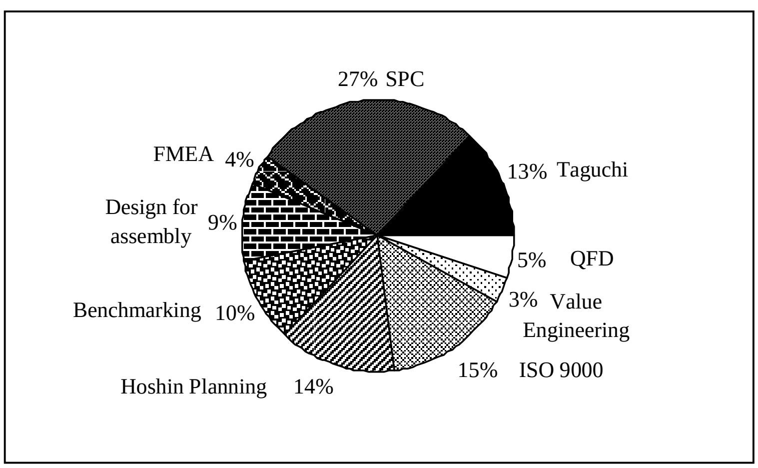
Appendix 4. History of integration of QFD and other techniques

Technique	Resource
Comprehensive QFD	Gustafsson (1995), Nakui (1991)
Computationa QFD	Reich (1995, 1996)
Concurrent QFD	Prasad (1998a, 2000)
Distributed QFD	Hrones et al. (1993), Ouyang et al. (1997)
Dynamic QFD with feedback loops	Adiano and Roth (1994)
Enhanced QFD	Burchill and Fine (1997), Clausing and Pugh (1991)
Extended QFD	Hales et al. (1994), Herrmann et al. (2000), Prasad (1998a)
Expert system-based extension to the fuzzy QFD	Verma et al. (1998)
Four stage model for performing software oriented QFD	Barnett and Raja (1995)
Medical software QFD	Hallberg et al. (1999)
Modified and extended QFD process for ecologically sustainable product design	Storen (1997)
Modified and extended QFD for Total Quality Healthcare	Lim and Tang (2000)
Modified QFD for collecting "Whats"	Dube et al. (1999)
Modified QFD for invisible or performance undifferentiating products	Hales (1993)
Modified QFD for services	Stuart and Tax (1996)
Process oriented improvement of QFD	Schmidt (1997)
Quality Benchmark Deployment (QBD)	Swanson (1993)
Service design QFD by a 3-matrix approach	Ermer and Kniper (1998)
Service Problem Deployment (SPD)	Dahlgaard and Kanji (1994)
Service QFD	American Supplier Institute (ASI) (1994)
Software QFD	Liu (2001), Ouyang et al. (1997), Yilmaz and Chatterjee (1997)
Statistically extended QFD	Rajala and Savolainen (1996)

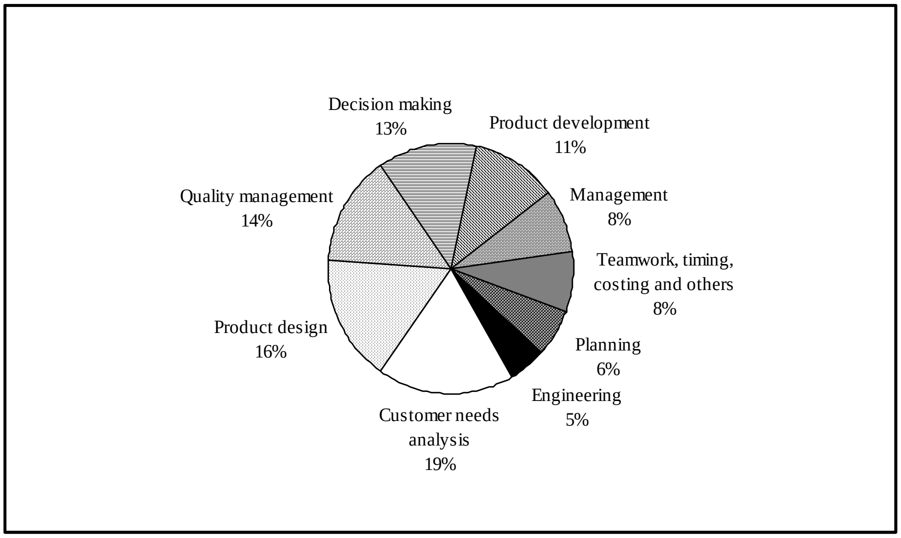
Appendix 5. Modified and extended QFD techniques



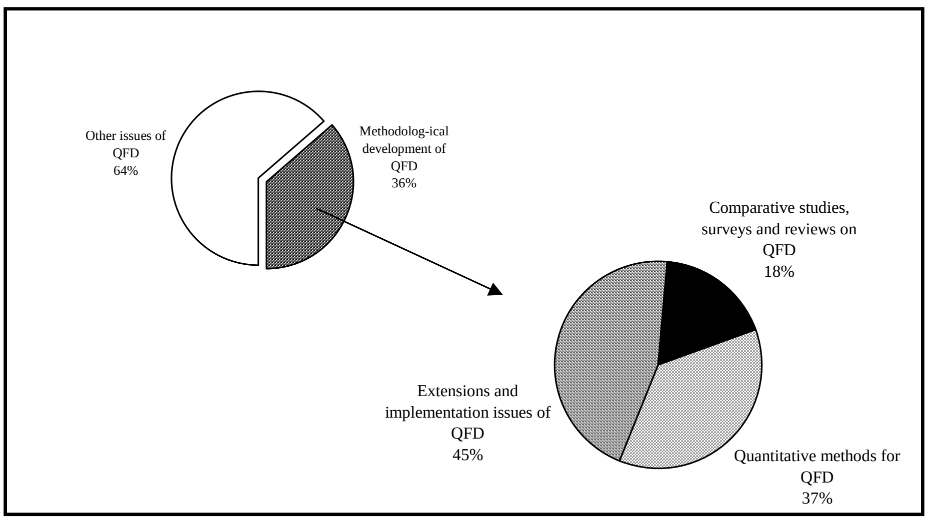
Appendix 6. Countries with experiences in applying QFD (Chan and Wu, 2002)



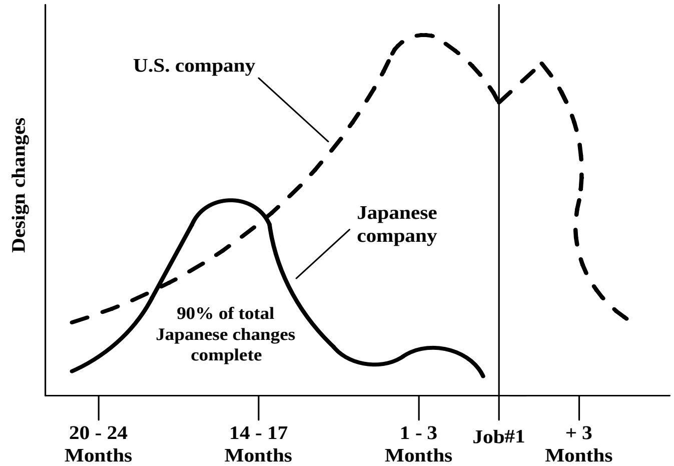
Appendix 7. Percentage of QFD publications compared to other quality techniques and standards (Bouchereau and Rowlands, 2000b)



Appendix 8. % of publications in functional fields of QFD (Chan and Wu, 2002)



Appendix 9. Methodological development of QFD (Chan and Wu, 2002)



Appendix 10. With and without QFD in Japan and America (Hauser and Clausing, 1996)