# THE ROLE OF QFD IN THE PRODUCT DEVELOPMENT PROCESS – A MULTIPLE CASE STUDY LEADING TO A PROPOSED FRAMEWORK

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*Abstract. Currently, a model for product development widely used is the stage-gate approach. The stages are where the product development activities occur and the gates serve as a go/kill decision point. However, other methods and tools should be used within the stages. One of these methods is QFD (Quality Function Deployment), adopted by a number of companies that helps to translate customer requirements into design quality characteristics. Quality is then deployed down stream into the product development in order to achieve customer satisfaction. Although the literature on the application of QFD usage for product development is relatively well-established, it is not completely clear in which stages QFD should be used and how intensively should be applied in them. In fact, there is no consensus of how QFD should be employed within the product development process. In this sense, the main object of this research is to study the role of QFD in the stage gate approach. In order to accomplish this objective, a brief literature review was carried out and a multiple case study in four companies was conducted. This paper presents the results of these case studies and proposes a framework for introducing QFD within the product development process.*

*Keywords. QFD, Product Development, Stage-gate, Quality Function Deployment*

## 1. Introduction

A number of development process has been proposed by various authors and institutions for the past years (Cooper, 1993, Clark and Wheelwright, 1993, Duncan, 1996, APQP, 1997; Peters et al., 1999). A model widely used is the stage-gate approach (by Cooper, 1993). Griffin (1997) states that the best practices for product development should be supported by the implementation of this approach. Currently, companies usually apply a product development process based on Cooper's model. It is based on five development stages (preliminary investigation, detailed investigation, development, testing and validation, and full production and market launching) and respective gates. Stages are where the action occurs in order to advance the project to a gate. Preceding each stage, a gate is a decision point which serves as a go/kill decision. However, other methods and tools should be used within the stages. One of these methods applied to product development is QFD (Quality Function Deployment), adopted by a number of companies. It helps to translate customer needs and wants into a technical concept or design quality characteristics. The quality is then deployed into the development process in order to achieve customer satisfaction.

Although the literature on the application of QFD for product development is relatively well-established (e.g. Akao, 1990; Mizuno and Akao, 1994; Cheng et al., 1995), it is not completely clear in which stages QFD should be used and how intensively the method is to be applied in these stages. Some authors (e.g. Cooper, 1993) claim that the method has particular applicability to stage 2 (preliminary investigation). However, only the first matrix is more suitable to this stage since others could be used in the subsequent stages (e.g. the matrix of manufacturing process characteristics). Other authors (e.g. Peters et al., 1999) suggest that the method can also be applied in the detailed investigation (stage 2) or development (stage 3). So, it seems that there is no consensus in the literature when (and how) QFD should be applied within the product development process. In this sense, the main object of this research is to study the role of QFD in the stage gate approach, according to each stage of process development.

This paper is an enhancement of previous work performed by a team involved with this project, coordinated by the author of the present article. The project has begun with an exploratory survey of which results were presented by Miguel and Carpinetti (1999). Then, a more extensive survey was carried out by increasing the sample and improving the questionnaire in both form and content, from which results can be found in Miguel (2003). A number of recommendations for further development were provided based on the findings (Miguel, 2003). These recommendations have lead to a more in-depth analysis. So, a second activity as part of the project was to conduct case studies in companies which have already achieved maturity in QFD application. This activity could help to explain why some gaps exist in implementing QFD in order to prevent companies from having similar disconnects. One of the gaps was related to QFD application within product development process. A multiple case study was then conducted in four companies by performing interviews and using published data. A more detailed analysis and results of these cases was presented by Formaggio (2003) and Miguel and Formaggio (2003). Besides to have a better understanding of QFD activities within the product development process, the exploratory case studies aimed at contributing to develop a framework on how QFD activities should be distributed through the stages of process development. A preliminary framework was proposed by Miguel (2002), based on the stage-gate approach. However, this framework was just exploratory. Therefore, the principal objective of this paper is to present a second version of the framework by combining the preliminary proposal with the performed case studies.

## 2. The Stage Gate Approach for Product Development

The development process of a product usually follows the sequence of an idea generation, investigation, design formulation, product production, after-production packaging and storing, and market launch. The literature presents a number of models for new product development (NPD). Clark and Wheelwright (1993) suggests four stages which comprises concept and development, product planning, product and process engineering and pilot production and ramp up. Analogously, Duncan (1996) presents similar four stages but includes a ‘zero’ stage called ‘exploration’. This is relevant since much attention should be paid at the initial stages due to the complexity involved with product development which tends to increase as the time goes by (Griffin, 1997). In this sense, the stage-gate system, proposed by Cooper (1993), is a interesting and useful approach. Griffin (1997) points out that the best practices for product development should be supported by the implementation of the stage-gate approach. This approach breaks the product project into discrete and identifiable stages, typically, four, five or six in number. Each stage is multifunctional and designed to gather information needed to progress the project to the next stage or decision point. The general flow of a generic stage-gate is shown in Fig. 1.

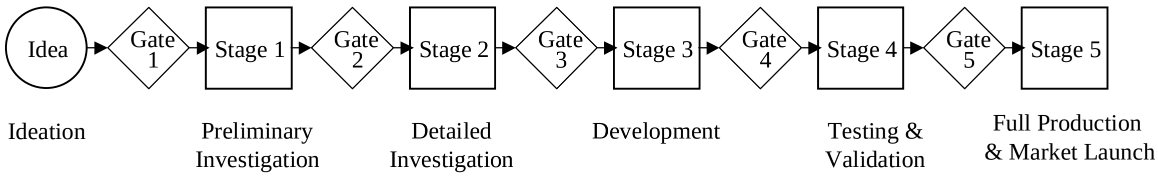


Figure 1. A Generic Stage Gate New Product Development Process (Cooper, 1993).

The key stages are (Cooper, 1993):
Stage 1) Preliminary investigation: a quick investigation and scoping of the project.
Stage 2) Detailed investigation: a much more detailed investigation, leading to a business case, including project definition and justification, and a project plan.
Stage 3) Development: the actual design and development of the new product.
Stage 4) Testing and validation: tests or trials in the marketplace, lab, and plant to verify and validate the proposed new product, and its marketing and production.
Stage 5) Full production and market launch: commercialization - beginning of full production, marketing, and selling.

Preceding each stage is a gate or a go/kill decision point. According to Cooper (1993), gates serves as quality control check points, as go/kill and prioritization decision points, and as points where the path forward for the next stage of the process is decided. Gates are predefined and specify a set of “deliverables”, a list of criteria, and outputs. They are usually manned by senior managers from different functions, sometimes as a project management committee.

## 3. Quality Function Deployment – Concept, Main Components and Application

QFD was conceived in Japan in the late 1960s, during an era when Japanese industries changed its mode of product development through imitation and copying and moved to product development based on originality. Akao firstly presented the concept and method of QFD in a transitional time when statistical quality control was being transformed to total quality control between 1960 and 1965 (Akao, 1998). One of the first reason for the development of QFD was to create a method that would assist in the process of designing new products thus assuring quality prior to production. In 1966, a process assurance items table was presented by Oshiumi of Brigestone Tyre Coporation (Akao, 1998). The table showed the links from the substitute quality characteristics, which were converted from true qualities, to the process factors. In 1972, the term quality deployment described this concept for the first time. Then, the concept was improved resulting in a quality chart that was created and made public by the Kobe Shipyards of Mitsubish Heavy Industry.

Beginning in the early 1980s, the QFD product development approach has been slowly adopted by American industry, starting with the automotive industry. Then, the application of the method was expanded to other industrial sectors including service organizations. In adopting QFD, manufacturing or service organizations can have its inherent benefits. From those inherent QFD benefits, the method has been implemented in many countries around the globe. Not only developed countries but also emerging economies have implemented QFD in order to improve their capacity of developing products and services. Among these developing nations, a lot of efforts have been put in companies operating in countries like Brazil. The method was firstly introduced in Brazil through an article presented at the International Conference in Quality Control held in Rio de Janeiro in 1989 (Akao and Ohfuji, 1989). More intensive dissemination occurred in the beginning of the 90's. Further information can be found elsewhere (Miguel and Cheng, 2001). The authors outline how QFD has been applied in the country for the past ten years or so.

### 3.1. QFD Concept

According to Akao (1998), Quality Function Deployment is a generic name for quality deployment and narrowly defined quality function deployment. Quality Deployment is defined as translating the user demands into substitute characteristics (quality characteristics), determining the design quality of a completed product, and systematically deploying the quality of each product system into that of each part and process element as well as the relationship among them. Narrowly defined QFD is defined as systematically deploying the job functions and operations that contribute to quality into step-by-step details. Figure 2 illustrates the definition of QFD proposed by Akao (1990; 1998).

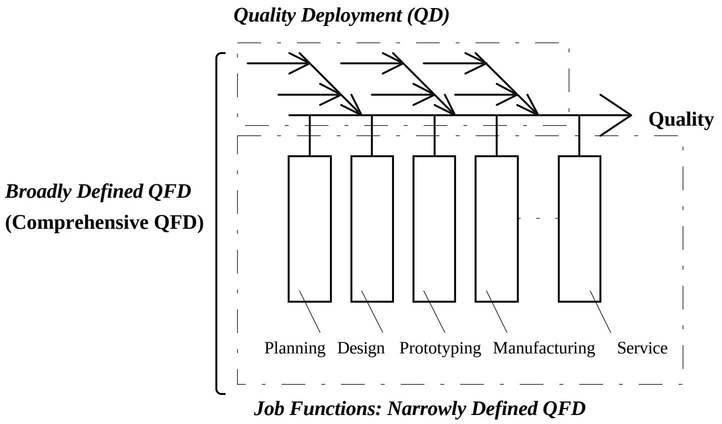


Figure 2. Definition of QFD by Akao (1990; 1998).

As can be seen in Fig. 2, broadly defined QFD consists of QD and narrowly defined QFD. In the USA, QFD and QD are infrequently distinguished and are trated as synonyms (Akao, 1998). This was also confirmed by Christiano et al. (2000). As a result, the majority of QFD applications in the USA are in fact Quality Deployment. Accordingly to the literature, this occur all over the world. In Brazil, for instance, the company tend only to use the quality matrix, i.e. the house of quality or QD, as identified by Miguel and Capinetti (1999) and Miguel (2003).

### 3.2. QFD Components

The main QFD components are: the deployment tables, the matrices, and the conceptual model. A quality deployment table is a chart which represents levels of deployment of a given subject. The table represents more details of the information available. The information is grouped by affinity (similarity) and ordered in levels from the left hand side of the table towards the right hand side. More detail is obtained from level one to levels two, three, and so on. The smaller the number of the levels, more subjective is the expression (information) related to the subject. The subject can be, for instance, the voice of customer, expressed by the demanded quality.

QFD utilizes a set of matrices to establish quality and deploy it through the product development. A matrix is a combination of two deployment tables. One of the most referred matrix is called the ‘house of quality’ (HOQ). It is a matrix which provides a map for the design process, as a construct for understanding customer requirements (demanded quality) and establishing priorities of design requirements (quality characteristics) to satisfy them. However, other matrices are also used in a cause-effect relationship. These matrices relates the variables associated with one design phase to the other variables associated with the subsequent design phase. Examples of these matrices are: product functions x quality characteristics, process parameters x quality characteristics, process parameters x raw material, etc.

A set of matrix used in a given development is called the conceptual QFD model. This model represents the whole development. It can consider a number of deployments, e.g. quality, technology, costs, and reliability deployments, as suggested by Akao (1990). The conceptual model also represents the ‘route’ to obtain the product and it is usually related to its production process (Cheng et al., 1995).

### 3.3. QFD Application

The sequence to apply QFD can be found in the work of Cheng et al. (1995). It can be divided into five main steps, namely: 1) determination of QFD project goals; 2) definition of the conceptual model; 3) development of the house of quality matrix; 4) development of other matrices; 5) definition of an action plan. A case of an accomplished implementation of these steps is presented elsewhere (Miguel et al., 2001). The steps are briefly described as follows:

Step 1) Determination of QFD project goals

Firstly, it is necessary to determine which goals the QFD project aims at achieving. These goals are usually related to quality, technology, reliability, costs, and market. Examples of projects goals are:

- Achieve a market share of 10% in the first two years (market);
- Increase product life in 5,000 cycles (quality);
- Reduce customer complaints of the existing model in a quarter (reliability).

Step 2) Definition of the conceptual model

A conceptual model is a representation of the set of matrices of a given development. The position of the matrices in the model depends on the cause-effect relationship present in the development process. Figure 3 illustrates a conceptual model for developing flexible films for packaging.

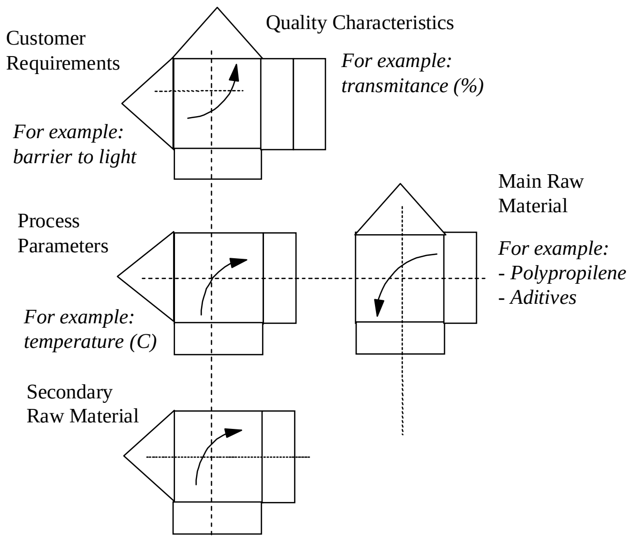


Figure 3. Example of a Conceptual Model (Miguel et al., 2001).

Step 3) Development of the house of quality matrix

The basic concept of QFD is to translate the desires of customers into product design or engineering characteristics. This is accomplished by using the house of quality (HOQ) matrix. This matrix relates customer requirements (CRs) with quality characteristics (QCs). Figure 4 shows an illustration of this matrix.

The HOQ presented in Fig. 4 shows: (1) CRs in rows and (2) QCs in columns, (3) their relationships within the matrix, i.e. the relationship ratings between CRs and QCs. The conventional HOQ employs a rating scale e.g., 1–3–9, or 1–5–9 to indicate the relation degree, i.e., weak–medium–strong of strength between CRs and QCs. Although the conventional approach to prioritizing QCs is easy to understand and use, there are several methodological issues associated with it. Part (4) is the determination of the degree of importance of CRs and the quality planning. There is also the incorporation of the correlations among QCs to a decision process for determining appropriate QCs (not showed in the matrix), i.e. the consideration of cost trade-offs among the QCs. Part (5) is dedicated to the QCs prioritization and the determination of the specification (it is usually used an adjustment of the relationship ratings between CRs and QCs, called normalization, in order to insure a more meaningful representation of the QC priorities).

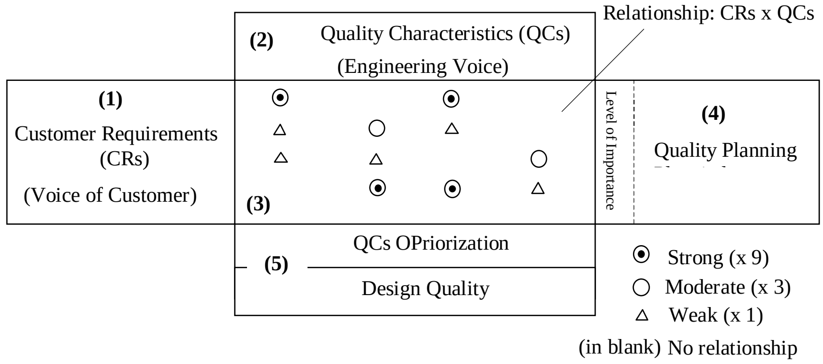


Figure 4. Customer Requirements *versus* Quality Characteristics (adapted from Miguel, 2001).

Step 4) Development of other matrices

Depending on the product development, other matrices can be developed. In fact, one of the main potential of QFD usage is the application of such matrices. Usually, only the first matrix (HOQ) is used by the companies, as identified by the literature (Christiano et al., 2000; Martins and Aspinwall, 2001 and Miguel, 2003). Examples of other matrices can be found in Miguel et al., 2001.

Step 5) Definition of an action plan

The main purpose of this step is to put the information of matrices into practice. Since QFD can be used for developing a new product or to improve an existing one, in the latter case a truly action plan is required as a result of the whole QFD effort. In the former case, the action plan can be implemented through narrowly define QFD. However, only a very few companies have apply it. Usually, they use other models to deploy function (the necessary work to obtain quality). The companies may use ISO 9000 (quality assurance) procedures or others (e.g. QS 9000, ISO TS 16949, TL 9000, AS 9001, depending on the industrial sector). Alternatively or even as a complement to quality assurance procedures, the companies may apply a structured process for new product development such as those pointed out earlier in section 2.

Other aspects which are relevant for QFD application is the management support, project definition, team selection, and frequency and duration of the meetings. In the initial phase, the scope of the project has to be established and should be communicated and agreed upon by management. Management support is always very important because all available expertise as well as market information will be required. Project definition is an important aspect to achieve success in QFD implementation. In order to turn a pilot project into a success, it is critical to select an appropriate product to be employed. A very complex product is not recommended since the team will have to develop the product at the same time they will be learning about the method (Miguel et al., 2001). Therefore, it is important to find a project with broad appeal which may pique interest from several areas of the company (Govers, 1996). A first project should be simple, but not trivial and represent a real opportunity for improvement. Nevertheless, it is not recommended to tackle the toughest company project in the first QFD effort (Govers, 1996). Teams should be cross-functional, expertise oriented, and consisting of about six members of comparable peer levels (Govers, 1996; Ohfuji et al., 1997). The meeting frequency and duration depend on the project and the necessary speed of the development towards a deadline. It is usually recommended weekly meetings at least, but more frequent meetings can be found as well (Miguel, 2003). The duration of the meetings usually varies from a couple of hours to one entire day (Miguel, 2003). The choice also depends on how urgent is the project. Obviously, the longer the meeting, the shorter time to market can be achieved. However, long meetings tend to be tiring and, eventually, ineffective.

Next section provides a brief review on some work related to QFD and some sort of product development process. It helps in establishing the context of this investigation.

## 4. QFD Application within Product Development Process – A Brief Literature Overview

A brief bibliography review related to both product development and QFD was conducted in order to study the role of QFD within the product development process. However, the literature does not provide details on how QFD should be used. Usually, the published material only indicates in which stage of product development the method is to be applied. Frequently, the literature points out just one stage. However, this can be particularly valid when only the house of quality is used. Since the method is more extensive than the HOQ, as outlined in the previous section, it seems not correct to apply the method in one stage alone. For instance, Cooper (1993) states that QFD has particular applicability to stage 2 (see Fig. 1). However, the author only concentrates in detailing the house of quality. Although other matrices are mentioned, they are neither fully explained or illustrated. The use of house of quality alone do not permit to achieve the whole QFD advantages and benefits. On the other hand, Rahman (1995) suggests an interesting proposal, called Taguchi-QFD approach. The author considers QFD as one of the important techniques for producing robust products, combined with Taguchi techniques. Nevertheless, further explanation on how QFD should be used within the development stages is provided. In fact, the QFD description is rather simplistic and, once again, restricted to the presentation of the house of quality. Gunasekaran (1998) presents QFD as a method within the concurrent engineering scope in a system called integrated product development-quality management (IPD-QM). The author claims that QFD can be used to develop such a system. However, how this could be carried out is not explained at all. Peters et al. (1999) present a generic model for new product development in which QFD is to be used as a tool in the ‘idea’ stage (within pre-design and development) and in the ‘concept’ stage (within design and development). Other tools and techniques are also mentioned (e.g. FMEA - Failure Mode and Effects Analysis, DFA/DFM - Design for Manufacturing and for Assembly, DOE - Design of Experiments, and other quality tools and techniques). Despite the citation of these tools, including QFD, none of them is further detailed.

Table 1 summarises some publications which establish a development process similar to the stage-gate and cite QFD as one of the methods to be used in one of the stages, mostly in the first or second stage of product development.

Table 1. Development process and QFD cited by the literature.

| Reference | Development Process | Number of Stages | Stage of QFD usage | Use of other matrices |
|---|---|---|---|---|
| Cooper, 1993 | Stage-gate | 5 | 2 | Only House of quality |
| Radhan, 1995 | Product development stages | 3 | 1 | Only House of quality |
| APQP, 1997 | APQP | 5 | 1 and 2 | Not available |
| Gunasekaran, 1998 | IPD-QM | Not available | Not available | Not available |
| Peters et al., 1999 | Generic model | 6 | 1 and 2 | Not available |

As can be seen in Tab. 1, the reviewed publications present different development process in terms of main focus and number of stages. Actually, they are distinct process but similar in nature. Most of them suggest in which stage QFD is to be used but only two of them provide further details regarding the matrix to be used. Those which mention the use of QFD matrices, suggest the use of HOQ matrix alone.

Although the literature review is not extensive, it demonstrates that a more in-depth analysis should be conducted to get a better understanding of QFD interaction within product development process. This analysis would support to develop a framework to establish the role of QFD method in the stages of development. Then, section 6 is devoted to present the multiple case study conducted in companies that have a structured development process in addition to the use of QFD. However, before presenting the cases, the research background is outlined in section 5.

## 5. Research Background

In 1999, a postal survey was conducted in a sample of 111 companies from different industrial sectors with the objective to gather knowledge on how companies were dealing with QFD. From a response rate of about 28%, a third was QFD users, of which about 13% had already implemented the method and around 19% of companies were implementing it. More interesting, nearly 30% stated they had plans to use QFD in the near future. Further details can be found elsewhere (Miguel and Carpinetti, 1999). Although this survey was useful to have an preliminary overall understanding of QFD application in Brazil there were some constraints. Almost all of these companies were from the manufacturing sector, chiefly the automotive sector although is one of which QFD is mostly applied (Akao, 1997). Moreover, the sample was limited and a three-page questionnaire did not explore all the necessary QFD aspects of practice, implementation and results. So, the survey had to be enhanced in terms of both method and approach.

Then, a more extensive survey was conducted. The report of the design, development and findings of this survey can be found in Miguel (2003). The sample population was not a stratified random but an intentional one, the top 500 Brazilian private organisations in annual sales. A mail survey was chosen due to a required small budget compared to company visits and telephone enquires despite of the better response rate of the last ones. Nevertheless, about 22% response rate was achieved, within Furtrell's (1994) expected range of 20 to 40% (502 questionnaires were sent). The companies were of different size and industrial sectors, classified according to industrial sectors based on the European Union industry classification (NACE, 1990). Approximately 21% of the surveyed companies were QFD users; most of them use the method since 1997. The companies reported the QFD experienced difficulties, perceived benefits, and other relevant aspects of its implementation. The main difficulties were relative to the size of the matrices, commitment of group members, and lack of experience. Companies were more likely to report qualitative benefits associated with improved cross-functional communication and teamwork. Although the study revealed a considerable lack of knowledge about the method expressed by many survey respondents, it identified some companies which reach a maturity level of QFD usage.

As a consequence of the previous study, a number of recommendations for further development were provided based on the findings. It was understood that some results have lead to a more in-depth analysis. So, a second activity as part of the whole project was to conduct case studies in companies which have already achieved maturity in QFD implementation. This activity can help to explain why some gaps exist in implementing QFD in order to prevent companies from having similar disconnects. These case studies are presented at the following session.

## 6. Case Studies

This section presents the concept of case studies, the methodology selected to conduct them and their results. The full description can be found in Formaggio (2003) and Miguel and Formaggio (2003).

Case study research has been recognised as being particularly good for examining the how and why questions (Yin, 1994). Additionally, in general, case studies are the preferred strategy when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context. Such “explanatory” case studies also can be complemented by two other types (Yin, 1994): “exploratory” and “descriptive” case studies. Voss et al. (2002) complement this by stating that in the early stages of many research programmes, exploration is needed to develop research ideas and questions, i.e. means to uncover areas for research and theory development. Exploratory case study can be considered for this work because this study began with setting some direction in order to understand how QFD has been applied within product development process. In a future stage, it is planned the development of the theory behind the application of the method. Additionally, a primary distinctions in designing case studies is between single- and multiple-case designs. The latter have distinct advantages and disadvantages in comparison to the former. The evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust (Yin, 1994). However, the conduction of a multiple-case study can require more extensive resources and time. From the perspective of this study, multiple-case study was chosen due to its inherent advantages. Previous investigation (Miguel, 2003) identified the companies where the cases should be studied, since each case must be carefully selected (Yin, 1994).

### 6.1 Methodology

The studied companies are involved in a diverse range of industries, such as automotive, food, capital equipment, and also differ in size, ownership and annual revenue. Semi-structured interviews with individuals involved with the NPD process were the main technique employed to gather the data. However, other methods such observation and document analysis were used as well. Interviews were also conducted with those personnel from functions which interface with the NPD process. In this way, a case study was build up for each company. More details of the methodology can be found in Formaggio (2003). Two basic questions were asked in the interviews, with subsequent queries according to the respondent answers. The interviews were tape-recorded typically during approximately two hours, on average. They were conducted by a team, within which one member directed the questions, another second occasionally participated to make some points clear, and a third one acted as an observer. When analysing the recordings some clarifications were necessary. Then, e-mails were sent to the companies to add information when necessary. Some company documentation was used as well. The data were formatted in a text, considering the following main issues: company profile, model of product development used by the company, QFD application in the company, and QFD usage within the product development process. The cases are described next.

### 6.2 Company A

This is an automotive company and it employs approximately 10,000 people. Currently, the company assemblies 30 models of lorries. It also produces chassis for buses as well as engines, spindles, and components for a number of industrial applications. Typical company developments include platform and derivative projects.

The product development process was created in its headquarter and is based on ten stages and gates regressively counted. The company applies QS 9000 (1998), and the requirements of APQP (Advanced Product Quality Planning) are employed in each stage. The gates respect a number of criteria based on a 'delivery fulfilment list', based on costs, quality and performance objectives as well as based on risk analysis.

QFD is one of the methods applied by the company during the development process. It uses the method in the first development stage to define product concept. The company does not apply all QFD deployments (technology, reliability, and costs). It claims that other tools are used to consider reliability and costs in the development process. Only quality deployment is applied. In fact, the deployment is restricted to the HOQ matrix. The company aims at translating market requirements into product concept. The method helps the company to put together marketing and R&D areas. To obtain the requirements, the company conducts qualitative research with its dealers. Then, a commercial benchmarking is performed where the current company product and the competitors are evaluated using a 1 to 5 Lickert scale. Typical number of customer requirements is 130 yielding 275 product specifications.

The company considers QFD a flexible method to be used in its stage-gate development process. It permits to achieve a clearer assessment of the main competitors. Other benefits include the break of some paradigms in the product engineering. Some product specification that the R&D considered important, QFD has shown that the customer does not agree. Additionally, the company claims that method strengthens the practice of simultaneous engineering.

### 6.3 Company B

Company B is a food company, ranked within the top 50 majors companies operating in the country. Its market share involves exporting approximately a third of its production and the company employs 30,000 people. The company produces frozen foods which include a variety of dishes as well as other meat products such as ham and sausage. Platform and derivative projects are included in the company portfolio. Its development capacity is quite significant; 100 products a year with high diversity.

The product development process comprises four stages based on the Deming cycle PDCA (plan-do-check-act). In fact, the company implemented TQC (Total Quality Control) in 1991, adapting the cycle to the following stages: market opportunities study (plan); development (do); implementation (check), and launch and monitoring (act). Each stage is deployed in three levels until reaching departmental activities and tasks. The company is one of the precursors of QFD application in the country and it can be considered as a benchmarking of QFD implementation. However, not all deployments are conducted. Emphasis is given to quality deployment. Not only the quality matrix is used (demanded quality x quality characteristics) but also others (quality characteristics with process parameters and raw material). Nevertheless, the company has intended to apply cost deployment, but never succeed.

QFD is applied in the first stage (market opportunities study), through the gathering of customer requirements. In the stage 2 (development), quality deployments are carried out not only supporting the definition of product specification but also developing production process and raw material requirements. Finally, in the stage 3 (implementation), QFD is used to transfer project specifications to the shop floor by establishing the process technical standards (PTS). PTSs are then deployed to the operational manufacturing process. Additionally, all specifications are used to the supply control items to the labs.

Although the company considers QFD relevant to its development process, the method is not compulsory to all new products. It depends on the type and complexity of the project.

### 6.4 Company C

The third company is a subsidiary of a transnational company, ranked in the global 500 majors companies. It produces machines to movement materials in the construction, mining, agriculture, forest, and manufacturing industry. Currently, the company manufactures 5 product lines, with 21 basic models and 30 distinctive configurations. The company exports about 70% of its production and it employs 2,300 people.

The development process was created in the company headquarter and it consists of five stages and gates (concept, development, production, launch, final evaluation). The gates area go/no go decision, divided into A (first revision), P (prototype), R (readiness), and A (shipping). It is a long term process (10 years or more), including revisions every three years. The platform projects are defined in company headquarter and then derivatives are developed accordingly to the characterises of the region in the globe, considering environmental and safety requirements. Generally, each machine can have different configurations, including three types of engines and a wide variety of accessories. The main challenge in the process development is to reduce the development cycle.

QFD is applied in the initial stage (concept) as one of the various available methods. Usually, the project is conducted with a world wide team. The first matrix is used to contemplate the differences in the products made for the USA, Brazil and other countries. When the QFD is finished, the company usually obtains a customer feedback to check if all demanded quality were fulfilled. Generally, the result of the concept is presented as a virtual model as a design-build test. Despite of the QFD importance for the company, the method is not mandatory, but the plan is that its use becomes compulsory.

### 6.5 Company D

The fourth case is about a company which produces bi-oriented polypropylene films (BOPP) used for packaging (biscuits, cigarette, ribbons, etc.) - transparent, opaque, and metalled flexible films. It employs 350 people with a market share of about 35% in Latin America. The company has a dozen of platforms, from which a number of derivative projects is derived from each platform, usually related to the main film characteristics.

The development process consists of six stages, namely: basic proposal, preliminary investigation, operational proposal, stage test 1, stage test 2 and conclusion. As the name suggests the basic proposal is a formalisation of the idea. Then, a preliminary investigation is carried out, followed by a project proposal. The stages test 1 and test 2 is, respectively, the first production tests and the production scale up. The conclusion is the final product validation. In this case, QFD is used in various development stages. In the first stages, its application is more detailed while its use in fourth and fifth stages is for validation purpose. As observed in the other cases, only quality deployment is conducted. Nevertheless, a set of matrices is employed when constructing a conceptual model. These matrices consider process parameters control, basic and special raw material. Currently, an attempt is being made to use cost deployment.

QFD is part of the three company initiatives to enhance its product development process: a portfolio management, a new structure for development based on stage and gates, and QFD to operate the development process. The method has been used since 2000. QFD has been applied in a total of 11 projects (five completed and six in development). The method brought a number of benefits to the company: reduction of complaints and return of products and a number of qualitative benefits such as improved team work and better communication between departments.

### 6.6 Summary of Results

Table 2 summarizes the results of the case studies regarding the product development process and QFD usage.

Table 2. Summary of the case studies.

| Company | Product and Production | Development Process | No. of stages | Stage of QFD usage | Use of other matrices |
|---|---|---|---|---|---|
| A | Assembly/make to stock | Stage-gate | 10 | 2nd | no (only HOQ) |
| B | No assembly/make to stock | PDCA Cycle | 4 | 1st, 2nd and 3rd | yes (some) |
| C | Assembly/make to order | Stage-gate | 5 | 1st | no (only HOQ) |
| D | No assembly/make to order | Stage-gate | 6 | 1st to 5th | yes (various) |

As expected, the case studies indicated that QFD tends to be applied in the first stages of product development. In addition, it does not seen that the application varies according to the type of product (assembly) or production configuration (make to order or make to stock) for all cases. One interesting remark is that the more complex is the development process, the simpler is the QFD application (e.g. company A and C). However, this might be related to the lack of knowledge of the whole QFD potential leading to a more restricted use of matrices (see Miguel, 2003).

## 7. A Proposed Framework for Conducting QFD within the Stage-gate Approach

Figure 5 presents a second version of a proposal to consider QFD activities within the stages of NPD (the first version can be found in Miguel, 2002). Further details of these QFD activities are described next.

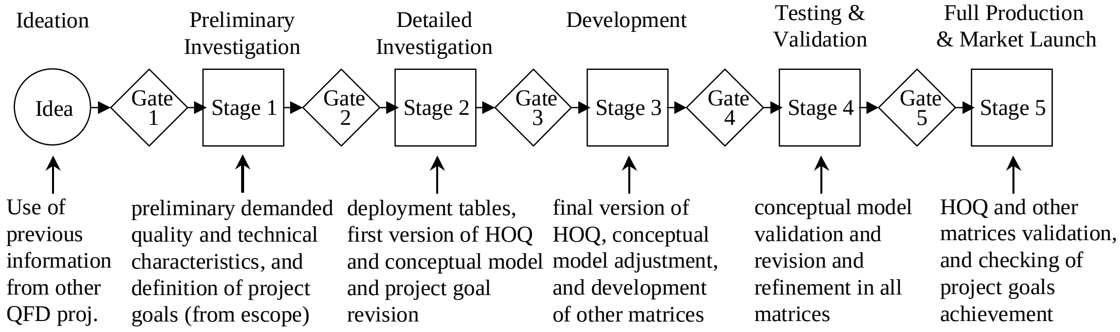


Figure 5. QFD activities within the stages of NPD.

**Ideation**

In this first stage, previous project in which QFD was applied can be used as a source of ideas. The source of these ideas might come from the market research conducted in those projects and records of the discussions in the teams. As mentioned by Cooper (1993), idea generation could come externally or internally from the company.

**Preliminary investigation**

Since this is a quick investigation, it is not recommended to spend too much time and resources in this stage. Nevertheless, it is relevant to have sufficient information to decide if the project progress to the next stage. Therefore, it is useful to have preliminary market demands by having some of introductory customer requirements. In this case, a quick consulting to the customer might be necessary. Customer who usually work as partners in previous developments may be listened to get these preliminary requirements. Additionally, it is important to have some technical design points, at least those more relevant relatively to the project scope. These technical design points, which would become quality characteristics in the subsequent stages, could consider the existing knowledge in the company and, if necessary, the support of technical consulting, externally or internally to the company. It is also necessary to define the project goals, usually using the information present in the scope of the project.

**Detailed investigation**

In this stage, QFD starts to be applied in its ordinary use, considering more details are necessary to investigate if the project could advance to the next stage. In this stage it is also vital to have a project definition and justification. Therefore, the project goals should be defined more precisely. It is also required to develop a first version of the conceptual model (see Fig. 3) to get a general idea of the number the matrices needed for the project. This could also help in defining the necessary resources since it involves an overview of the whole project. In this stage, deployment tables should be proposed as well. Usually, it will involve demanded quality from customers and quality characteristics from company research and development. Using the available information, a preliminary HOQ matrix can be proposed. Perhaps, there would be parts of the matrix not fill in, especially those parts that depends on having a more detailed market analysis or benchmarking possible competitors. Anyway, this matrix would support the decision in the next gate.

**Development**

Since this stage is the actual design and development of the new product, all previous information should be completed. Firstly, an adjustment of the conceptual model would be required. Then, the HOQ should be filled in completely, resulting in all quantification that this matrix can offer. Further, the team is able to develop the other matrices considered in the conceptual model. Typical matrices involve process parameters control, raw material, and so on. The first production tests would bring some inputs to the HOQ and process matrices.

**Testing and validation**

This stage usually requires tests or trials in the marketplace or in the plant to verify and validate not only the proposed new product but also its production. Therefore, there is an opportunity to check all product and production variables. The matrices could help to do so, since they provide an extensive map of the whole development. The conceptual model can be then validated and a refinement and final revision of the matrices can be carried out. This revision would help to confirm all the performed tests including those related to the production ramp-up.

**Full Production and marketing launch**

Since this stage consists of full-production, marketing, and commercialisation of the product, it would be possible to confirm some of the project goals, especially those related to quality (e.g. specification fulfilment) and technology (e.g. new function achievement). Reliability and market goals might require some time for product in the market. After a given period, project goals related to market share, number of defects, returned products, etc. can be assessed. The production scale-up might indicate if all matrices can be finally validated. Customers would be able to assess the product and company could feedback this information to corrective actions and continuous improvement.

## 8. Concluding Remarks

This work cannot be conclusive yet, since the proposed framework should be reviewed and validated. This is currently being carried out through an action research (see Thiollent, 1996) in a company within the packaging industrial sector. Nevertheless, some concluding remarks can be pointed out:

- Regarding the case studies, they do not completely show how QFD should be applied according to each development stage. One remark is trustworthy: the method is not applied in its all potentialities, considering other deployments are not conducted and in most cases only the first matrix (HOQ) is employed. Therefore, further research on this direction would be desirable. Secondly, it seems that companies with a more robust development process tend to use the method more simplistically. On one hand this restricts the benefits from its application. On the other hand, its simplifies its use since some companies see it as too complex and cumbersome. As a consequence, further investigation to get a full understanding of QFD within NPD would be necessary, e.g. by studying other companies identified in the survey (Miguel, 2003).

- Concerning the framework, the proposal should be further developed. Once again, more in depth case studies would be helpful for enhancing the proposal and validating it. The improvement could consider to provide more details of the QFD application in each development stage. For instance, it would be beneficial to identify QFD measures to be used as criteria in the gates. This is another suggestion for future investigations that this research will be concentrated.

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