OPTIMIZATION OF THE PRODUCT DESIGN THROUGH QUALITY FUNCTION DEPLOYMENT (QFD) AND ANALYTICAL HIERARCHY PROCESS (AHP): A CASE STUDY IN A CERAMIC WASHBASIN

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ABSTRACT

OPTIMIZATION OF THE PRODUCT DESIGN THROUGH QUALITY FUNCTION DEPLOYMENT (QFD) AND ANALYTICAL HIERARCHY PROCESS(AHP): A CASE STUDY IN A CERAMIC WASHBASIN

QFD is a methodology, which establishes a relationship between product and customer, determines product's sales ability and carry out it to a high level during the process.

In this study, QFD methodology, which is used in several industries, was implemented in the sanitary production industry. In this purpose, the washbasin, which is called as 'Potsink' produced by Vitra, was chosen and examined implementation ability of the methodology. The aim for this choice is that Potsink's design is different from usual washbasin forms and because of this reason, some sales problems would be appeared also there are some ergonomical and functional problems was observed.

In the first step, which is developed by the customer's voice, Analytic Hierarchy Process AHP was used. The relationship, which is between product and customer's requirements, is determined by Analytic Hierarchy Process AHP.

After this step, with customer requirements and technical details, which is matched with, are put in the house of quality (HoQ). Fallowing this step, improvement ratio and sales points are taken place in the house. Finally calculate all items and evaluated.

ÖZET

ÜRÜN TASARIMINDA KALİTE FONKSİYON YAYILIMI (KFY) VE ANALİTİK HİYERARŞİ SÜRECİ (AHS) YÖNTEMLERİYLE ÜRÜN OPTİMİZASYONU: SERAMİK LAVABO ÖRNEĞİ

QFD yöntemi, ürün ile müşteri arasındaki ilişkiyi sağlayan, ürünün satılabilirliğini belirleyen ve yöntem süresince yapılacak iyileştirme ile ürünün satılabilirliğini arttıran bir yöntemdir.

Bu çalışmada, birçok sektörde uygulama alanı bulmuş QFD yönteminin vitrifiye seramik ürün tasarımlarında uygulanması ele alınmıştır. Bu amaçla inceleme ürünü olarak Vitra'nın Potsink lavabosu seçilmiş ve QFD'nin seramik ürünlerindeki uygulanabilirliği denenmiştir. Bu ürünün seçilmesindeki neden; Potsink tasarımının alışılagelmiş lavabo tasarımlarından farklı oluşu ve bu farklılıktan kaynaklı satış kaygılarının olması, ayrıca tasarımında ergonomik ve fonksiyonel bazı problemlerin gözlemlenmesidir.

Yöntemin ilk basamağını oluşturan, müşterinin sesi aşamasında Analitik Hiyerarşi Süreci (AHS) metodu kullanılmıştır. Bu metot ile ürün hakkında belirlenen müşteri beklentilerinin bir biri arasındaki hiyerarşik ilişkisi belirlenmiştir.

Daha sonra, belirlenen müşteri beklentileri ile bunlara karşılık gelen ürünün teknik özellikleri Kalite Evi'nde bir birleri ile ilişkilendirilmiştir. Kalite Evi'ne giren satış avantajı ve iyileştirme oranları ile hesaba katılan bu veriler hesaplanmış ve ortaya çıkan veriler değerlendirilmiştir.

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CHAPTER 1

INTRODUCTION

1.1. Definition of The Problem

Ceramic production industry in Turkey has demonstrated considerably progress during the past decades. In addition to the rapidly changing technology in the sector, diversified expectations of the customer and the augmenting competition among the companies orient the companies to search for original and easily applicable solutions. At the competitive conditions of the markets, for the customer satisfaction, optimizing the product within the frame of definite costs is almost the only way of the company to become stable at the market as well as to become a brand. The role of the QFD method here gains significance in the meaning of simplifying the product process and increasing the sales advantages while the optimizations implemented on the products are satisfying the customer demands. The ceramic product we have selected does not only gain significance with its aesthetical properties such as shape, color and material due to the increasing competition condition of the market, but also, with the ergonomic, antropometric, anti-bacterial and hygenic properties as understood with the QFD application.

1.2. Objectives of The Study

This study aims at examining the applicability of Quality Fuction Deployment (QFD) and Analytical Hierarchy Process (AHP) to shift customer expectations and design quality into the product through a case study on the ceramic washbasin. For this purpose we determined customer needs and product requirements through direct interviews, observation and data analyses. We quantified and prioritized the customer needs on the hierarchy diagram providing accurate ratio-scale priorities. Following the categorization and prioritization of customer needs, the requirements were then converted into quality characteristics. Consequently in this case-study, QFD and augmented it with the AHP can be successfully applied in the case and findings demonstrate that some solutions can be suggested for optimization of the product effectively.

1.3. Methods of The Study

This study has been constructed on five chapters to consider the aims.

The first chapter is introductory chapter comprising the definition of the problem, aims and method of the study.

The second chapter consists of the literature researches about Quality Function Deployment (QFD) which is related to the product design and Anayltic Hierarchy Process (AHP).

The third chapter is a brief desription which gives the process of the Quality Function Deployment (QFD), Analytic Hierarcy Process (AHP) and related applications.

The fourth chapter is the implementing of the QFD in a ceramic washbasin. In this chapter we start with the Voice of Customer VOC analyse. This analyse's results gives Customer Requirements and then we evaluated these outputs with Analytic Hierarchy Process AHP. This process gives weights of the customer requirements and these inputs are transfered into the House of Quality (HOQ). HOQ is a basic QFD matrix which includes customer requirements, their weights, technical attributes and sailing paramaters.

The fifth chapter, which is the findings, results are shown and in the sixth chapter which is conclusion, results are evaluated.

1.4. Limitations of The Study

Determining of limitations of the study is important for evaluating right results. For this reason, we limited the project with some factors which we meet during the project process.

The first limitation of the study is that the company was not actively involved. Interviews were realized in the company's local stores with sales directors. We discuss about the company's customer profile and something about the product which we work on.

The second factor were about testing the product. When we started to project in 2007, the company had not started to production of the “Potsink” yet. However, during our literature searching, production process was started.

As an other limitation, we didn’t plan benchmarket because there is not any product which is in the same sales area in other companies.

Another limitation was about costs. We worked on the project independent from costs to receive customer’s raw needs and expectations. However, due to QFD is a method which includes repeats in production process, the company will be able to continue with results and they can do a cost analyse.

As a final limitation, we did not include any sales strategies or advertisements which increase sales guaranties.

CHAPTER 2

LITERATURE REVIEW OF QUALITY FUNCTION DEPLOYMENT (QFD) AND ANAYTICAL HIERARCHY PROCESS (AHP)

2.1. History of Quality Function Deployment (QFD)

Before scrutinizing QFD in detail, we would like to tell its historical development process and design. Quality Function Deployment (QFD) was conceived in Japan in the late 1960s, during an era when Japanese industries broke from their post-World War II mode of product development through imitation and copying mode and moved to product development based on originality. QFD was born in this environment as a method or concept for new product development under the umbrella of Total Quality Control. After World War II, statistical quality control (SQC) was introduced to Japan and became the central quality activity, primarily in the era of manufacturing. Later, it was integrated with the teachings of Dr. Juran, who during his 1945 visit to Japan emphasized the importance of making quality control a part of business management, and the teaching of Dr Kaoru Ishikawa, who spearheaded the Company Wide Quality Control movement by convincing the top management of companies of the importance of having every employee take part. This evolution was fortified also by the 1961 publication of Total Quality Control by Dr Feigenbaum. As a result, SQC was transformed into TQC in Japan during this transitional period between 1960 and 1965

It was during this time that Dr Yoji Akao first presented the concept and method of QFD. The Japanese automobile industry was in the midst of rapid growth, going through endless new product development and model changes. At that time, the following two issues became the seeds out of which QFD was conceived.

1. People started to recognize the importance of design quality, but how it could be done was not found.

2. Companies were already using QC process charts, but the charts were produced at the manufacturing site after the new products were being churned out of the line. (QFD Institute 2008)

The purpose of Professors Mizuno and Akao was to develop a quality assurance method that would design customer satisfaction into a product before it was manufactured. Prior quality control methods were primarily aimed at fixing a problem during or after manufacturing.

The first large scale application was presented in 1966 by Kiyotaka Oshiumi of Bridgestone Tire in Japan, which used process assurance used fishbone diagram to identify each customer requirement and to identify the design substitute quality characteristics and process factors needed to control and measure it.

In 1972, with the application of QFD to the design of an oil tanker at the Kobe Shipyards of Mitsubishi Heavy Industry, the fishbone diagrams grew unwieldy. Since the effects shared multiple causes, the fish bones could be refashioned into a spreadsheet or matrix format with the rows being desired effects of customer satisfaction and the columns being the controlling and measurable causes.

At the same time, Katsuyoshi Ishihara introduced the Value Engineering principles used to describe how a product and its components work. He expanded this to describe business functions necessary to assure the quality of the design process itself. Merged with these new ideas, QFD eventually became the comprehensive quality design system for both product and business process.

The first seminar (a 2 day seminar) in Japan was organized in 1983 by Japan Productivity Center, and was followed by many others. The introduction of QFD to America and Europe began in 1983 when the American Society for Quality Control published Akao's work in Quality Progress and Cambridge Research (today Kaizen Institute) invited Akao to give a QFD seminar in Chicago. This was followed by several QFD lectures to American audiences sponsored by Bob King and GOAL/QPC in Boston.

Today, QFD continues to inspire strong interest around the world, generating new application, practitioners and researchers each year. Countries that have held national and international QFD Symposium to this day include the U.S. Japan, Sweden, Germany, Australia, Brazil, and Turkey (QFD Institute 2008).

Dr. Akao is one of the few to receive the prestigious Deming Prize for Individuals as well as the Best on Quality Award from International Academy for Quality. He was also awarded the inaugural Distinguished Service Medal from the American Society for Quality. He is an author of many published articles and books including Quality Function Deployment: Integrating Customer Requirements into

Product Design and QFD: the Customer-Driven Approach to Quality Planning & Deployment. Dr. Akao is chairman of the International Council for QFD and the senior advisor to the QFD Institute.

Two distinguished awards have been established in recent years in his honor. The Akao Prize® is awarded to individuals around the world who have demonstrated Excellence in their practice and dissemination of QFD for many years (QFD Institute 2008).

2.2. QFD Applications in Product Optimization Literature Review

QFD was originally developed and implemented in Japan at the Kobe Shipyards of Mitsubishi Heavy Industries in 1972. It was observed that Toyota was able to reduce start up pre-production costs by 60% from 1977 to 1984 and to decrease the time required for its development by one-third through the use of QFD (Hauser and Clausing 1988, Ertay 1998, Hsiao 2002). Early users of QFD include Toyota, Ford Motor Company, Procter, 3M Corporation, Gamble, AT&T, Hewlett Packard, Digital Equipment Corporation, etc. (Cohen 1995). Besides, the American Supplier Institute (ASI) in Dearborn, Michigan and GOAL/QPC (Growth Opportunity Alliance of Lawrence/Quality Productivity Center) in Methuen, Massachusetts have been the primary organizations offering an overview and workshop type training since QFD was introduced to the United States in the early 1980s (Prasad 1998).

QFD was originally proposed, through collecting and analyzing the voice of customer, to develop products with higher quality to meet or surpass customer's needs. Thus, this primary functions of QFD are product development, quality management, and customer need analysis. Later QFD's functions had been extended to wider field such as design, planning, decision-making, engineering, management, teamwork, timing and costing (Chan and Wu 2002).

QFD is a useful tool for developing the requirements of new products, and its benefits are well documented (Clausing and Cohen 1994, Cohen 1995, Hauser and Clausing 1988, King 1989).

QFD is a customer-driven design process. Its use is essential in product design (Cohen, et al. 1995). Sullivan defines QFD as an overall concept that provides a means of translating customer requirements into the appropriate technical requirements at each stage of product development and production (i.e. marketing, planning, product design, and engineering prototype evaluation, production process development, production sales). Many QFD methodology development and applications have been published by Kim, Mrad, Persson et al., Gerling et al., Han et al., Yoram and Eyal, Chan and Wu, Bhattacharya et al. And Dweiri and Kablan, Poel, Lai et al., 2007. Various applications within the literature can be grouped under three categories as: QFD implementations before the design stage; QFD implementations during the design stage and QFD implementations after the design stage (Dikmen, et al. 2005).

2.3. Literature Review of Product Design as A Functional Field of QFD

QFD was originally proposed, through collecting and analyzing the voice of the customer, to develop products with higher quality to meet or surpass customer's needs. Thus, the primary functions of QFD are product development, quality management, and customer needs analysis. Later, QFD's functions had been expanded to wider fields such as design, planning, decision-making, engineering, management, teamwork, timing, and costing. Essentially, there is no definite boundary for QFD's potential fields of applications.

QFD can be referred to as designed-in quality rather than traditional inspected-in quality in the sense that it helps a company shift from inspecting the product's quality to designing quality into the product through customer needs analysis (Guinta and Praizler 1993). Therefore, product design is also a functional field of QFD as illustrated in (Acord 1997, Bahrami 1994), (Belhe and Kusiak 1996), (Bodell and Russell 1989), (Colton and Staples 1997), (Conley 1998), (De Vera et al. 1988), (Elboushi and Sherif 1997), (Filling et al. 1998), (Fox 1993), (Gershenson and Stauffer 1999), (Halbleib et al. 1993), (Harding et al. 1999, 2001), (Karbhari et al. 1991), (Kim and Moskowitz 1997), (Logan and Radcliffe 1997), (Moskowitz and Kim 1997), (Nibbelke et al. 2001), (Nichols and Flanagan 1994), (Reed 1995), (Reich 2000), (Reich et al. 1996), (Remich 1999), (Rosenthal 1992), (Steiner et al. 1992), (Storen 1997), (Swackhamer 1985), (Wang 1999), (Wei et al. 2000), (Wu and Wu 1999), and (Yang et al. 2000). There are a wealth of studies in this field focusing on the design of different products as well as on the different issues in product design, including 3D geometry-based product design (Fuxin, et al. 2001), course design (Burgar 1994, Gustafsson, et al. 1999), design for manufacturability (Fabricius 1994, Youssef 1994), design methods (Esteghlalian, et al. 1998, Frank and Green 1992, Hovmark and Norell 1994, Huang and Mak 1999, 2001, Killander 2001, Sivaloganathan, et al. 1995, 2001), design of information systems and services (Hallberg 1999), designing customer-driven marketing programs (Mohr-Jackson 1996), engineering design (Hazelrigg 1996, 1998), flight control design (Joos 1999), housing design (Abdul-Rahman, et al. 1999), information system design (Hallberg, et al. 1999b), instructional design (Murgatroyd 1993), internal service system design 1999, manufacturing system design (Monplaisir, et al. 1997), process design (Ferguson 1990), product concepting (Burchill and Fine 1997, Shillito 1992b), product definition (Anonymous 1995a, Aldrich and Stauffer 1995, Hales 1993a), product/process innovation (Presley, et al. 2000, Voss 1994), product redesign (Anonymous 1993a, Hauser 1993), product/service introduction (Nolle 1993), questionnaire design (Glushkovsky, et al. 1995), robust design (Kraslawski, et al. 1993), service design (Ermer and Kniper 1998, Franceschini and Terzago 1998, Selen and Schepers 2001, Stamm 1992), system design (Dowlatshahi and Ashok 1997, Chapman, et al. 1992, Tan, et al. 1998), system redesign (Goodstein and Butz 1998), training module design (Shaffer and Pfeiffer 1995), and value design (Shillito 1992a).

2.4. Literature Review of Anayltic Hierarchy Process (AHP)

The analytic hierarchy process (AHP), an important mathematical method introduced by Saaty (1977, 1980, 1988, 1994, 2000), has been accepted as a leading and flexible modelingmethodology and applied to lots of research aspects for the resolution of complex problems (Zahedi 1986, Logan 1990, Carlsson and Walden 1995, Ramanathan and Ganesh 1995, Leung, et al. 1998, Kurttila, et al. 2000; Lai, et al. 2002, Yurdakul 2004, Sundarraj 2004). AHP has great advantage over other mathematical models or methods, which is reflected in the consideration of subjective and judgmental information from both practitioners and academics, and the solution of discrete multiple criteria decisive problems. Meanwhile, AHP application in pest management has not yet been reported. Traditional ratio of cost to profit on the basis of economics (Kahraman, et al. 2000, Stefani, et al. 2001, Wedley, et al. 2001, Ghajar and Khalife 2003, Intriligator 2004, Lee 2005) has been applied in many aspects to evaluate the superiority of different strategies. Traditional pest management strategy is also centered on economy. However, the complex system including economic, social and ecological systems should be taken into consideration as the object instead of economic system only, regardless of any method of pest management. As we all know, every strategy has both cost and profit to the complex eco-system. Here, we suggest that the positive effect of different strategies used in the complex system be called Comprehensive Profit (CP)—including economic, ecological and social profit. The negative effect can be called Comprehensive Cost (CC)—including economic, ecological and social cost. An index system of CP and CC can be constructed accordingly. To evaluate the superiority of different strategies, an index of Ratio of Comprehensive Cost to Comprehensive Profit (RCCCP) is presented, and a RCCCPmodel is constructed based on the AHP. This produced the matrix of RCCCP, where the RCCCP indexmatrixWcc/Wcp is defined as the index optimization matrix of CC divided by the index optimization matrix of CP. The RCCCP model with AHP is used to evaluate the priority of different pest-control measures in IPM. Theoretically, the lower the value of RCCCP is, the more superior the corresponding strategy is. The strategy with the lowest value should be accepted and applied in management practices.

CHAPTER 3

METHODOLOGY OF QUALITY FUNCTION DEPLOYMENT (QFD) AND ANALYTIC HIERARCHY PROCESS (AHP)

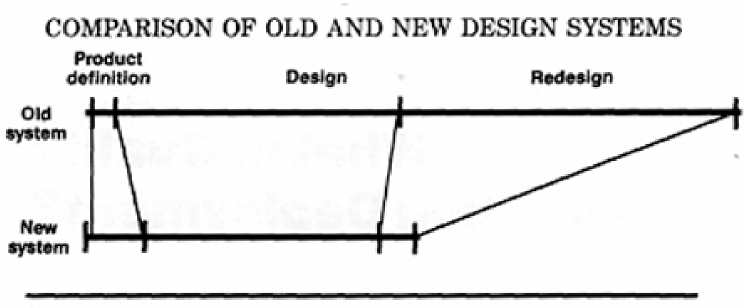
3.1. Definition of Quality Function Deployment (QFD)

Quality Function Deployment, or QFD as it is commonly known, is a process that provides structure to the development cycle. This structure 'can be' likened to the framework of a house. The foundation is customer requirements. The frame consists of the planning matrix, which includes items such as the importance rating, customer-perceived benchmarking, sales point, and scale-up factors. The second floor of the house includes the technical features. The roof is the trade-off of technical features. The walls are the interrelationship matrix between the customer requirements and the technical characteristics. Other parts can be built using things such as new technologies, functions, technical characteristics, processing steps, importance ratings, competitive analysis, and sales points. The components utilized are dependent upon the scope of the project.

The thing that makes QFD unique is that the primary focus is the customer requirements. The process is driven by what the customer wants, not by innovations in technology. Consequently, more effort is involved getting the information necessary for determining what the customer truly wants. This tends to increase the initial planning time in the project definition phase of the development cycle, but it reduces the overall cycle time in bringing a product to market. This is illustrated in Figure1, which is reproduced with permission from GOAL/QPC.

Table 1. Comparison of Old Design Systems.

(Source: Bossert,1991)



When a product is conceived, the primary focus is on who the customer is, since the customer sets the stage for all the work. What the customer wants will determine whether new technologies are needed, whether simple improvements are possible, or whether a revolutionary concept is required. Success in determining customer requirements is directly related to success in the marketplace. This is critical to the whole process (Bossert 1991).

3.2. Definition Types of Customer Requirements and Kano Model

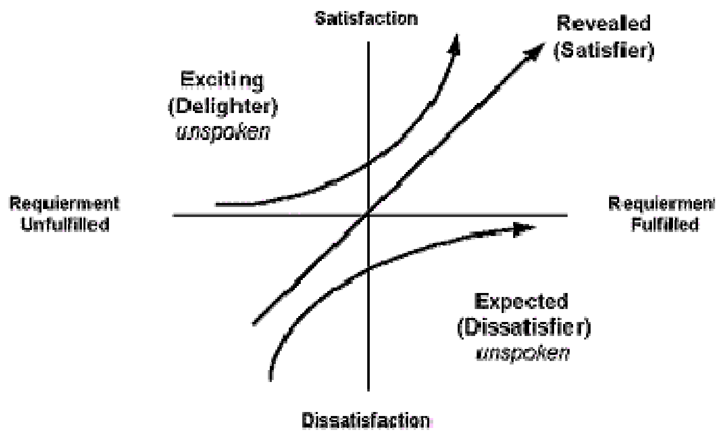
Customer requirements give the most important datas for the QFD projects. Accordingly, analyzing these requirements is also important as much as receiving to them. To satisfy customers, we must understand how meeting their requirements effects satisfaction. There are three types of customer requirements to consider.(Kano, et al. 1984). You can see in table 2.

Revealed Requirements are typically what we get by just asking customers what they want. These requirements satisfy (or dissatisfy) in proportion to their presence (or absence) in the product or service. Fast delivery would be a good example. The faster (or slower) the delivery, the more they like (or dislike) it.

Expected Requirements are often so basic the customer may fail to mention them- until we fail to perform them. They are basic expectations without which the product or service may cease to be of value; their absence is very dissatisfying. Further, meeting these requirements often goes unnoticed by most customers. For example, if coffe served hot, customers barely notice it. If it is cold or too hot, dissatisfaction occurs. Expected requirements must be fulfilled.

Exciting Requirements are difficult to discover. They are beyond the customer's expectations. Their absence does not dissatisfy; their presence excites. For example, if caviar and champagne were served on a fligt, that would be exciting. If not, customers would hardly complain. These are the things that wow the customer and bring them back. Since customers are not apt to voice these requirements, it is the responsibility of the organization to explore customer problems and opportunities to uncover such unspoken items.

Table 2. Kano Model: Product and services must meet all three types of requirements- not just what the customer say, (Source: Mazur, 2006)



Kano's model is also dynamic in that what excites us today is expected tomarrow. That is, once introduced, the exciting feature will soon be imitated by the competition and customers will come to expect it from everybody. An example would be the ability to have pizza delivered in thirty minutes. On the other hand, expected requirements can become exciting after a real or potential failure. An exaple might be when the passengers apploud after a pilot safely lands to airplane in rough and stormy weather.

Fulfilling these requirements leads to more than proportional satisfaction. If they are not met, however, there is no feeling of dissatisfaction. The advantages of classifying customer requirements by means of the Kano method are very clear:

· Priorities for product development. It is, for example, not very useful to invest in improving must be requirements which are already at a satisfactory level but better to improve one-dimensional or attractive requirements as they have a greater influence on perceived product quality and consequently on the customer's level of satisfaction.

· Product requirements are better understood: The product criteria which have the greatest influence on the customer's satisfaction can be identified. Classifying product requirements into must-be, one-dimensional and attractive dimensions can be used to focus on

· Kano's model of customer satisfaction can be optimally combined with quality function deployment. A prerequisite is identifying customer needs, their hierarchy and priorities (Griffin and Hauser 1993). Kano's model is used to establish the importance of individual product features for the customer's satisfaction and thus it creates the optimal prerequisite for process oriented product development activities.

· Kano's method provides valuable help in trade-off situations in the product development stage. If two product requirements cannot be met simultaneously due to technical or financial reasons, the criterion can be identified which has the greatest influence on customer satisfaction.

· Must-be, one-dimensional and attractive requirements differ, as a rule, in the utility expectations of different customer segments. From this starting point, customer-tailored solutions for special problems can be elaborated which guarantee an optimal level of satisfaction in the different customer segments.

· Discovering and fulfilling attractive requirements creates a wide range of possbilities for differentiation. A product which merely satisfies the must-be and one-dimensional requirements is perceived as average and therefore interchangeable (Hinterhuber et al, 1994). In the following we will explain how product requirements can be classified by means of a questionnaire. The ski industry, where more than 1500 customers were interviewed, is used to demonstrate how product requirements are ascertained, how a questionnaire is constructed, how the results are evaluated and interpreted and used as the basis for product development. (Cohen 1995).

The Kano Model has an additional dimension regarding which customer segments the target market includes.

Thus, eliminating problems is similar to meeting expected requirements. These is little satisfaction or competitive advantage when nothing goes wrong. Conversely, great value can be gained by discovering and delivering on exciting requirements ahead of the competition. QFD helps assure that expected requirements do not fall through the cracks and points out opportunities to build in excitement. (Mazur 1996)

3.3. Benefits of QFD

Since QFD is a customer-driven process, it creates a strong focus on the customer. QFD exercises tend to look beyond the usual customer feedback and attempt to define the requirements in a set of basic needs, which are compared to all competitive information available. Therefore, all competitors are evaluated equally both from the customer's perspective and from a technical perspective. Once this information is in hand, then, through a Pareto ranking, the requirements are prioritized, and the manager can then effectively place resources where they can do the most good-on the requirements that are meaningful to the customer and that can be acted upon.

Another benefit of QFD is that it structures experience and information into a concise format. In many companies, there is a wealth of information available but not put together in a document. QFD places that information into a structured format that is easy to assimilate. This information contains all necessary rationale for choosing the design, identifying trade-offs, and listing future enhancements. This is important for the times when there are personnel who leave the project and new people are brought on board, as the documentation allows for the swift integration of ideas and progress. QFD is also flexible enough to adapt to new information, since the matrix structure will grow or shrink based on the information received. In essence, QFD produces a living document, one that reacts to input and better defines real needs.

The QFD process is a very robust process. This means that things can be changed in the structure, but when done correctly, the top results do not really change. One QFD exercise involved the development of twenty-five customer requirements. The Project leader decided to address the top eight for further development work. He was concerned that if the importance ratings changed, the priority of the requirements would change. A computer program was set up so that all the importance ratings could be changed, holding everything else constant. The result was that the top eight items were always the top eight items, that only the order of occurrence changed. For example, the number one item might move to number three on the priority listing. This goes a long way in relieving concerns that managers may have when going through the QFD exercise. As people work through the QFD process, a team grows. It is one of the best approaches for developing teamwork, since all decisions are based on consensus and a fair amount of discussion takes place. This discussion allows everyone to explain their views, reach a consensus, and move forward on the project. People feel that all their interests are addressed, not always to their satisfaction, but at least their opinions are heard. This communication at the functional interface is critical. As people see what the larger picture is, individual concerns may not be as critical and some rationalization takes place. The process also identifies what actions need to take place so that all team members see how they fit into the overall project. This solidifies the team membership aspect and encourages teamwork. All these benefits summarizes in table 3, (Bossert 1991).

Table 3. Benefits of QFD

(Source: Bossert 1991)

CUSTOMER DRIVEN REDUCES	Creates focus on customer requirements Uses competitive information effectively Prioritizes resources Identifies items that can be acted upon Structures resident experience/information
IMPLEMENTATION TIME	Decreases midstream design change Limits post-introduction problems Avoids future development redundancies Identifies future application opportunities Surfaces missing assumptions
PROMOTES TEAMWORK	Consensus based Creates communication at interfaces Identifies actions at interfaces Creates global view out of details
PROVIDES DOCUMENTATION	Documents rationale for design Is easy to assimilate Adds structure to the information Adapts to changes, a Living Document Provides framework for sensitivity - analysis

3.4. Definition of Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is perhaps the most wellknown and widely used multi-criteria method. It has firm theoretical underpinnings and has been used successfully to help people make better decisions in a wide variety of complex circumstances (Golden, et al. 1989) (Vaidya and Kumar 2006). A main strength of the AHP is that it is both methodologically sound and user-friendly. Its ease of use is due to a unique combination of design characteristics. The AHP frames a decision as a hierarchy, an organizational framework many people are already familiar with and easy to explain to those who are not. All inputs consist of comparisons between just two decision elements at a time; pairwise comparisons like these are generally considered to be one of the best ways to elicit judgments from people (Reynolds and Jolly 1980). The output is easy to understand because it is based on simple scales derived from the pairwise comparisons. Finally, there is a built-in measure of the consistency of the judgments being made which both checks the reliability of the analysis and reduces the chance of making a procedural mistake.

3.5. The Modern Blitz QFD

Blitz QFD was developed by Richard Zultner for his clients in the software industry in the 1990s. The premise was that the House of Quality and other large matrices demanded too much time and resources when speed of development was a critical customer need. The Blitz QFD is an efficient subset of Comprehensive QFD as developed by Dr. Yoji Akao, that can be later upgraded with no wasted effort. Blitz QFD runs through all dimensions and phases new product development (analysis, design, development, and implementation but only on a few threads based on the top critical customer needs. Since this requires extremely sharp focus from the beginning, several new tools were added to QFD.

The essential elements of the method include the basic elements of the QFD method, except that the matrices usually employed are replaced by 2-3 elements at each level of analysis which represent the top-weighted elements in the traditional House of Quality. Typical techniques used to identify these top-level elements include some comparison method such as Utility or Pairwise comparison process (such as the

Analytic Hierarchy Process). Another way to view this approach is to think of these elements as the major "causes" identified in an Ishikawa diagram, carrying only these few elements forward using QFD transformation techniques, (Revelle, et al. 1998)

3.5.1. Seven Principles of Modern Blitz QFD

There are seven basic principles behind Modern QFD;

1. Focus with priority
2. Understand the causes
3. Understand the situation
4. Market-in vs Product-out
5. Define the process
6. Better communication
7. Listen to the “voice of the customer”

3.5.1.1. Focus with Priority

Each of the Management and Planning tools are used to address fundamental QFD principles.

Prioritization allows the organization to focus their human and financial resources to deliver maximum value to the customer. Random improvements are replaced by aligning set efforts to what matters most to the customer.

How can we know what matters most to the customer? The analytic Hierarchy Process (AHP) is a method to help customer accurately tell us themselves what are their priorities. These priorities can then be shown as a hierarchy of customer needs (Mazur 2008).

3.5.1.2.Understand the Causes

Another fundamental principle of QFD is cause-effect relationship. Causal factors are typically the constituents of our products, such as product attributes, design elements, processes, and other issues related to our product and technology. Effects are outcomes that lead to benefits to the customer.

The fishbone diagram has been a staple of quality analyses, and is important to understanding QFD. We can use it in two modes.

First is when the customer voices product features he would like to have. We use the fishbone diagram to understand the underlying and often unspoken benefits he expects to receive if these features are provided. In this case, the "spine" of the fishbone points you the left, from the causes to effects. In fact, one cause can even result in many effects, just as one product feature can provide many benefits. For complex analyses we can use a table format instead of the "bones". This is the Customer Voice Table.

Second is later in the QFD process, once the customer has prioritized the most important needs. For these top needs, we reserve the fishbone diagram to understand what product features, design, development, and implementation issues to adress first. In this case, the "spine" of the fishbone points to right, from the effect to causes. Each effect can result in several causal factors to be adressed at different stages of the product development process. For complex analyses where the causal factors can have multiple likages, we can use a table format instead of the 'bones'. This is the Maximum Value table. This table points out where we need to concantrate our resources to best satisfy the customer, (Mazur 2008).

3.5.1.3. Understand the Situation

Go to Gemba: to gain knowledge by direct sensory experience in the "actual place" where your customer benefits from your product. Where does the customer have the problems that you can help them with? We want to capture the "raw" information about this special place.

Companies that don't go to the Gemba are missing something: the details.

The Japanese have a world to describe "the true source of information" – Gemba. In manifacturing, gemba refers to the shop flor. When there is a problem, the engineers go directly to the work area and use their own eyes to see, their own ears to hear, their own hands to touch, etc. They rely on direct experience to understand the relevant situation we might help them realized.

Unlike other customer information gathering techiques, such as focus groups and surveys, here we do not ask questions about problem with out technology or marketing. We do not remove customers to an artificial site such as a meeting room, and we do not rely on customers' memories to report problems to us. Rather, we employ all of our senses and field research methods for the larger purpose of trying to understand where and how we might help customers (Mazur 2008).

3.5.1.4. Market-in vs. Product-out

One of the most critical business process is new product development. Without new products, an organization becomes stale, isolated from its customers, and may be forced to complete by lowering proces on existing products.

A fundamental QFD principle is to drive product development by beginning with the customer's need (market-in), rather than how the product can be changed or enhanced (product-out). Any oarganization claiming to be customer-centered must understand:

1. For a business to achive its goals and objectives, requires delivering products and services to customers that solve their key problems, enable opportunities, or enhance their well-being in physical and emotional ways. Thus, developers must understand what "jobs" their customers are trying to do, and issues they face and design functionally, emotionally, and cost effective solutions. And they must get it right the first time – trial and error is too costly.

2. To do this, developers must understand and communicate customer needs throughout their organization to assure that each department is focusing their best efforts on delivering quality as the customer defines it, efficiently. Or each department risks working at cross purposes to each other, to the customer, and ultimately to the business.

Since the business goals, customers, and departmental processes differ from company to company, QFD can not be a cookbook or a "one size fits all" method. It must be tailored to assure that each step adds value to the business, the customer, and the product (Mazur 2008).

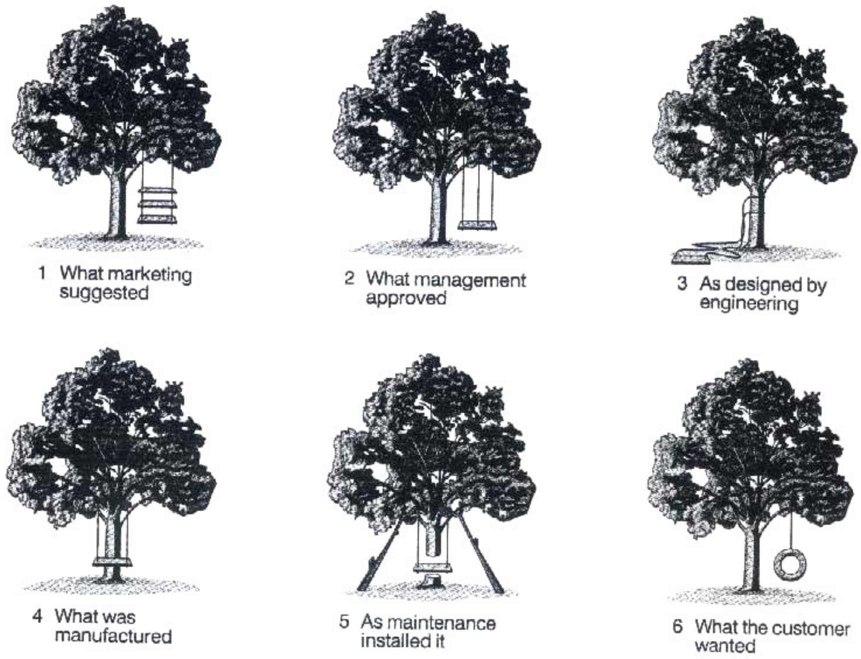


Figure 1. What Really Customer Need

(Source: Oakland 2000)

3.5.1.5.Defined Process

Another fundamental principle of QFD is that maximum benefits to your organization results from continued use of method. The learning curve can be step, so it is best to "depreciate" this over multiple projects over time. Further, the information acquired and the charts created can be re-used, often with little more then mirror revision after validating with current market conditions. Finally, industry leadership comes from holding previous gains and adding to them with each succeding product generation, and spreading lessons learned across all product families and business divisions.

As many organizations are facing retirements of their most expensive employes, or are looking to outsource work, there is a need to capture and make explicit the rationale, the experiences, and the tacit or implicit knowledge of these people. Your tailored QFD Process Flow supported by your case studies, will help build this Knowledge Management database (Mazur 2008).

3.5.1.6.Better Communication

Once of the most frequently cited reason for doing QFD is to improve communications within the organization. As a socio-tehnical system, QFD addresses both internal and external communications at both the human level and the technique level.

Many of Management and Planning plus (7MP+) tools are “techniques” specifically tuned to accomodate verbal data – the language of customers. Powerful enough when used indepedently, the tools give even more advantage to groups that can link them in a systematic way. Your tailored QFD process is precisely that (Mazur 2008).

Table 4. Social-Technical Relationship
(Source: QFD Turkey Symposium Notes, 2008)

Social	Technical
Multifunctional team	Linked series of tools
“Rules of engagement” with customer and workers	Documentation od decision making process
Customer focus overrides departmental focus	Apply lesson learned throughout organisation
	Reduce training time

3.5.1.7. Listen to the ‘Voice of Customer’

A common misunderstanding among QFD and other quality professionals concerns what the “Voice of Customer” is. In the most cases, it is necessary to go beyond the started requirements in order to build a competitive and profitable product. Why? State or voiced requirements can be met by any competitor who has access to them. This has led to a comoditization of products that differ little within a certain price point. In such case, the way to succeed is by lowering price, which is not always a long-term strategy for everyone.

The QFD approach is to uncover unspoken needs by analysis based on going to the Gemba and adding observational data, and even self-image and lifestyle concerns even before our customer can articulate them to our competitors.

Then, we can clarify these with the customer, have them give us their priorities, and then quantify a competitive solution and assure its quality throughout the development and production process.

Many of the basic tools already mentioned, such as the gemba visit table and log, customer process model, customer voice table, affinity diagram, hierarchy diagram, and the analytic hierarchy process facilitate this analysis (Mazur 2008).

CHAPTER 4

STEP BY STEP QUALITY FUNCTION DEPLOYMENT (QFD) AND ANALYTIC HIERARCHY PROCESS (AHP)

4.1. Determination of the Target of The Project

In this first step of the project, the target must be defined. This step also includes literature researchs and reseach plan.

4.2. Determination Key Customers

During the QFD process, the team will be making many judgments. They will be estimating the relationships between product or service capabilities and customer needs, for instance. In order to make these judgments meaningfully, the team will need to make clear and consistent definitions.

The team's most important underlying assumptions will be those about the customer.

From the experiences, it is surprisingly difficult for product development teams to agree on who their customer is.

The first step in defining the key customer is to make a list of all possible candidates. The affinity diagram is a useful tool for managing this list of customers. To identify several customer groups, start by brainstorming all possible customers of the product or service you are planning. After identifying several customer groups, the second step is to focus on the key customers. Once the customer groups have been identified, deciding on the key customers is sometimes easy. Everyone glances at the list of customer groups and with little or no disagreement; they decide who the key customers are. If everyone cannot quickly agree on the key customer group, one of the other methods for selecting the key customer group may be useful. Prioritization Matrix and Analytical Hierarchy Process can be given as examples of these methods.

4.3. Meeting with Customers, Gemba

Before starting to identify customer needs, the key customer must be determined. For this purpose, Gemba is used in this step. The Gemba is where the product or services becomes of value to the customer, that is, where the product actually gets used. In Gemba, we determines who is actually our customer and what their problems and needs about the product. ın the gemba that we actually see our customers are, what their problems are, how the product will be used by them, etc. we go to Gemba in QFD to see our customer's poblems and opportunities as they happen, (Mazur 1996).

A Gemba visit is often simply called a customer visit. The hallmarks that make it uniquely useful are:

- the purpose is firstly to observe, occasionally to question, rarely to guide or direct
- the visit occurs in the context where the product or service is used, which allows direct observation of problems that arise, work arounds that are applied, and capabilities or services that are never used
- sometimes the customer (or client or user) is asked to describe what he is doing while he is doing it; this provides insight into the thought processes, which often reveal differences between the customer's mental model and the model of the developers or providers of the product or service.
- the customer will often express wishes or needs while working in context that would be forgotten or suppressed in a different context such as a structured interview or sales meeting

Common cases for a customer visit include:

- enhancing the features or usability of products (especially software) or devices (especially ones aimed at very broad or very niche consumers)
- improving processes or tools

4.3.1. How many Gembas?

In a study, reported by Pouliot (1992), about 70% of customer requirements were captured in as few as ten to twelve gemba visits. Additional visits yielled little more than repetitious data. Since the purpose of the gemba visit is to get an understanding of cutomer voices, not a statistically valid sample from which to determine preferences and choice, it takes much less effort than other quantitative research methods. It has been the author's experience that fifteen gemba visits are sufficient to elicit nearly all revealed requirements (the 70%) and that the other 30% which represent the unspoken expected and exciting requirements can be analyzed with the Voice of Customer tools and techniques.

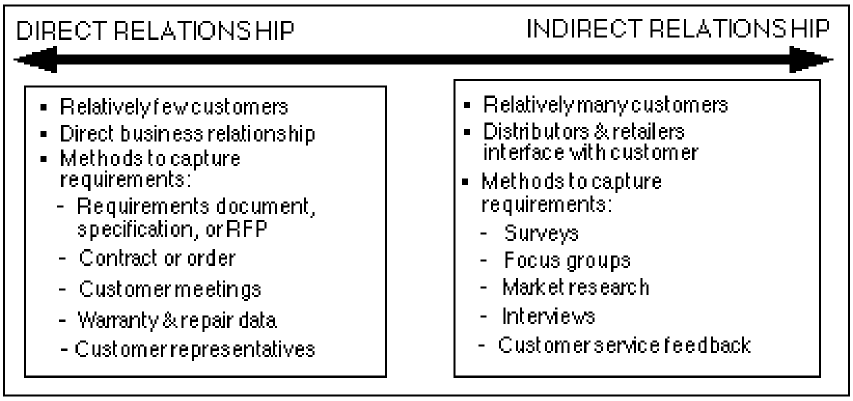
Since the number of customer's visits is small, it is best to optimize them by focusing on customers who are significant to the success of the project, (Mazur 1996)

4.4. Voice of the Customer

Once a product plan is established which defines the target market and customers, the next step is to plan how to capture these customer's needs for each development project. This includes determining how to identify target customers, which customers to contact in order to capture there needs, what mechanisms to use to collect their needs, and a schedule and estimate of resources to capture the voice of the customer (project plan for product definition phase).

As opportunities are identified, appropriate techniques are used to capture the voice of the customer. The techniques used will depend on the nature of the customer relationship as illustrated below.

Table 5. Nature of The Customer Relationships.
(Source: Mazur1996)



There is no one monolithic voice of the customer. Customer voices are diverse. In consumer markets, there are a variety of different needs. Even within one buying unit, there are multiple customer voices (e.g., children versus parents). This applies to industrial and government markets as well. There are even multiple customer voices within a single organization: the voice of the procuring organization, the voice of the user, and the voice of the supporting or maintenance organization. These diverse voices must be considered, reconciled and balanced to develop a truly successful product.

Traditionally, Marketing has had responsibility for defining customer needs and product requirements. This has tended to isolate Engineering and other development personnel from the customer and from gaining a first hand understanding of customer needs. As a result, customer's real needs can become somewhat abstract to other development personnel.

Product development personnel need to be directly involved in understanding customer needs. This may involve visiting or meeting with customers, observing customers using or maintaining products, participating in focus groups or rotating development personnel through marketing, sales, or customer support functions. This direct involvement provides a better understanding of customer needs, the customer environment, and product use; develops greater empathy on the part of product development personnel, minimizes hidden knowledge, overcomes technical arrogance, and provides a better perspective for development decisions. These practices have resulted in fundamental insights such as engineers of highly technical products recognizing the importance to customers of ease of use and durability rather than the latest technology.

Where a company has a direct relationship with a very small number of customers, it is desirable to have a customer representative(s) on the product development team. Alternately, mechanisms such as focus groups should be used where there are a larger number of customers to insure on-going feedback over the development cycle. Current customers as well as potential customers should be considered and included. This customer involvement is useful for initially defining requirements, answering questions and providing input during development, and critiquing a design or prototype.

The number of customers depends on complexity of the product, diversity of market, product use, and the sophistication of customers. The goal is to get to the 90-95% level in capturing customer needs. Research for a range of products indicates that, on average, this is 20 customers.

Current customers are the first source of information if the product is aimed at current market. In addition, its important to talk with potential customers. Potential customers are the primary source of information if the product is aimed at new market. In addition, talk with competitor’s customers. They provide a good source of information on strengths on competitor's products and why they don't buy from us. Lead customers are a special class of coustomers that can provide important insights, particularly with new products. Lead customers are those customers who are the most advanced users of the product, customers who are pushing the product to its limits, or customers who are adapting an existing product(s) to new uses.

During customer discussions, it is essential to identify the basic customer needs. Frequently, customers will try to express their needs in terms of HOW the need can be satisfied and not in terms of WHAT the need is. This limits consideration of development alternatives. Development and marketing personnel should ask WHY until they truly understand what the root need is. Breakdown general requirements into more specific requirements by probing what is needed. Challenge, question and clarify requirements until they make sense. Document situations and circumstances to illustrate a customer need. Address priorities related to each need. Not all customer needs are equally important. Use ranking and paired comparisons to aid to prioritizing customer needs. Fundamentally, the objective is to understand how satisfying a particular need influences the purchase decision.

In addition to obtaining an understanding of customer needs, it is also important to obtain the customer's perspective on the competition relative to the proposed product.

This may require follow-up contact once the concept for the product is determined or even a prototype is developed. The question to resolve is: How do competitive products rank against our current or proposed product or prototype?

4.5. Organizing Customer Needs

Once customer needs are gathered, they then have to be organized. The mass of interview notes, requirements documents, market research, and customer data needs to be distilled into a handful of statements that express key customer needs. Affinity diagramming is a useful tool to assist with this effort. Brief statements which capture key customer needs are transcribed onto cards. A data dictionary which describes these statements of need are prepared to avoid any mis-interpretation. These cards are organized into logical groupings or related needs. This will make it easier to identify any redundancy and serves as a basis for organizing the customer needs.

In addition to "stated" or "spoken" customer needs, "unstated" or "unspoken" needs or opportunities should be identified. Needs that are assumed by customers and, therefore not verbalized, can be identified through preparation of a function tree. Excitement opportunities (new capabilities or unspoken needs that will cause customer excitement) are identified through the voice of the engineer, marketing, or customer support representative. These can also be identified by observing customers use or maintain products and recognizing opportunities for improvement.

4.6. Analytic Hierarchy Process (AHP)

4.6.1. Scope of AHP

The AHP proposes a methodology to organize the analytical thought, according to three basic principles, (Bautista 2007)

• *The hierarchy construction principle*: The AHP underlying assumption is that complex systems can be better understood through decomposition into essential elements. These elements can be the criteria involved in the considered decision problem, and be hierarchically structured into several levels, according to the relative importance of each element with respect to another one. The highest level represents the main decision objective, while the lowest one is constituted by the different alternatives.

• *The priority setting principle*: Human beings are able to intuitively perceive relationships between two elements, to express a preference of one on the other and to numerically evaluate this preference. This is still true regarding subjective considerations, since the idea is to translate a feeling. However, a fixed priority scale must be implemented in order to make the evaluation independent from the different orders of magnitude that characterize each element. From the synthesis of this pairwise judgment set is derived the priority scale between all the considered elements.

• *The logical consistency principle*: The comparisons evoked in the previous paragraph must respect one constraint, namely transitivity. For instance, considering three events *A*, *B* and *C*, if *A* is better than *B* and *B* better than *C*, then *A* must be better than *C*. Moreover, if *A* is twice better than *B* and *B* is three times better than *C*, then *A* must be six times better than *C*: this would constitute a perfectly consistent judgment. Nevertheless, perfect consistency cannot be expected because of the subjective character of the evaluated comparisons and of the changing circumstances: for instance, the same decision-maker might express different choices at two different moments.

The AHP technique thus involves quantitative and qualitative aspects into a unique analysis structure in order to convert the natural thoughts of any human being into an explicit process. This latter is implemented in a decision-support tool that provides objective and reliable results, even under different scenarios occurrence. It is worth noting that, being subjective the perceptions of the priority scale provider (i.e. the manager), the AHP method does not integrate the possible existence of an "always true, correct, immutable" decision.

The AHP main steps include (Wang 2007):

(1) *Hierarchy design step*: All the elements interfering into the decision-making problem must be determined and structured into levels as a family tree. The first level consists of the primary or main objective while the following ones are devoted to the secondary aims, etc. In the lowest level are the alternatives, i.e. the possible solutions of the multicriteria problem (and so, in the case considered in the study, the non-dominated solutions provided by the Pareto sort): this phase allows clarifying the problem components and their interaction.

(2) *Development of judgment matrices*: One of the main features of the AHP technique is its pairwise comparison working mode, for all the criteria (or alternatives)

belonging to the same hierarchical level. Judgment matrices can then be defined from these reciprocal comparisons. The pairwise comparisons are based on a standardized evaluation schemes (cf. next subsection).

(3) *Computing of local priorities*: Several methods for deriving local priorities (i.e. the local weights of criteria or the local scores of alternatives) from judgment matrices have been developed, such as the eigenvector method (EVM), the logarithmic least squares method (LLSM), the weighted least squares method (WLSM), the goal programming method (GPM), etc. Consistency check should be implemented for each judgment matrix.

(4) *Alternative ranking*: An aggregation procedure accounting for all local priorities (thanks to a simple weighted sum) then enables to obtain global priorities regarding the main objective, including global weight of each criteria or global scores of each alternative. The final ranking of the alternatives is determined on the basis of these global priorities.

4.6.2.Computational Details

Assume that n decision factors are considered in the quantification process of the relative importance of each factor with respect to all the other ones. This problem can be set up as a hierarchy as explained in the previous section. The pairwise comparisons will then be made between each pair of factors at a given level of the hierarchy, regarding their contribution toward the factor at the immediately above level. The comparisons are made on a scale of 1–9, as shown in table 6. This scale is chosen to support comparisons within a limited range but with sufficient sensitivity (a psychological limit for the human beings to establish quantitative distinction between two elements was proved by psychometric studies). These pairwise comparisons yield a reciprocal (n,n)-matrix A, where $a_{ii}=1$ (diagonal elements) and $a_{ji}=1/a_{ij}$.

Table 6. Value scale for alternative decision comparisons
(Source: Saaty 1980)

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

Suppose that only the first column of matrix $\underline{\boldsymbol{A}}$ is provided to state the relative importance of factors $\underline{2,3,\ldots,n}$ with respect to factor 1. If the judgments were completely consistent, then the remaining columns in the matrix would be completely determined due to the transitivity of the relative importance of the factors. However, there is no consistency except for that obtained by setting $\underline{a_{ji}=1/a_{ij}}$. Therefore, the comparison needs to be repeated for each column of the matrix, i.e. independent judgments must be made over each pair. Suppose that after all the comparisons are made, the matrix $\underline{\boldsymbol{A}}$ includes only exact relative weights.

Multiplying the matrix by the vector of weights $\underline{\boldsymbol{w}=(w_1,w_2,\ldots,w_n)}$ yields:

$$Aw = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & \cdots & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_1 \\ \cdots & \cdots & \cdots & \cdots \\ w_n/w_1 & \cdots & \cdots & w_n/w_n \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix}.$$

Therefore, to recover the overall scale from the matrix of ratios, the EVM was adopted. (Zeng, 2007). According to the previous equation, the problem can formulate as $\boldsymbol{Aw}=n\boldsymbol{w}$ or $(\boldsymbol{A}-n\boldsymbol{I})=0$, which represents a system of homogenous linear equations ($\boldsymbol{I}$ is the identity matrix). This system has a nontrivial solution if and only if the determinant of (***A***-*n**I***) vanishes, meaning that n is an eigenvalue of ***A***. Obviously, ***A*** has unit rank since every row is a constant multiple of the first row and thus all eigenvalues except one are equal to zero. The sum of the eigenvalues of a matrix equals its trace and in this case, the trace of ***A*** equals n. So, n is an eigenvalue of ***A*** and a nontrivial solution. Usually, the normalized vector is obtained by dividing all the entries $\boldsymbol{w}_i$ by their sum.

Thus, the scale can be recovered from the comparison matrix. In this exact case, the solution is any normalized column of ***A***. Notably, matrix ***A*** in this case is consistent, indicating that its entries satisfy the condition $a_{jk}=a_{ji}/a_{ki}$ (transitivity property).

4.6.3. Consistency

However, in actual cases, precise values of $\boldsymbol{w}_i/\boldsymbol{w}_j$ are not available, but their estimates, which in general differ from the ratios of the actual weights, are provided by the decision-maker. The matrix theory illustrates that a small perturbation of the coefficients implies a small perturbation of the eigenvalues. Therefore, an eigenvalue close to n, which is the largest eigenvalue $\lambda_{\max}$, should be found since the trace of the matrix (equal to n) remains equal to the sum of the eigenvalues while small errors of judgment are made and other eigenvalues are non-zero.

The solution to the problem of the largest eigenvalue, which is the weight eigenvector $\boldsymbol{w}$ that corresponds to $\lambda_{\max}$, when normalized, gives a unique estimate of the underlying ratio scale between the elements of the studied case. Furthermore, the matrix whose entries are w_i/w_j remains a consistent estimate of the "actual" matrix ***A*** which may not be consistent. In fact, ***A*** is consistent if and only if $\lambda_{\max}=n$. However, the inequality $\lambda_{\max}>n$ always exists. Therefore, the average of the remaining eigenvalues can be used as a "consistency index" (CI) which is the difference between $\lambda_{\max}$ and n divided by the normalizing factor (n-1).

$$\mathbf{CI} = \frac{\lambda_{\max} - n}{n - 1}.$$

The CI of the studied problem is compared with the average RI obtained from associated random matrices of order n to measure the error due to inconsistency, (Saaty 1980). As a rule of thumb, a consistency ratio (CR=CI/RI) value of 10% or less is considered as acceptable, otherwise the pairwise comparisons should be revised,(Aguilar-Lasserre, et al. 2009).

4.7. Technical Attributes

In this step, customer’s needs turns into the technical attributes which povides customer’s requirements. For this purpose, these attributes must be measurable and being direct relationship with customer’s needs.

At first, raw customer expectations is transformed into the benefits. After that, .features are determined according to benefits. This analyze helps us to translate voice of customers into voice of engineers. Thus, tecnical attributes are determined for each customer requirements.

In fallowing, we analyse Cause and Result relationships to understand whole production process and their effects on technical attributes. For this reason, we use Ishikawa Diagram.

4.7.1. Cause and Result Relationship: Ishikawa Diagram

The cause & effect diagram is the brainchild of Kaoru Ishikawa, who pioneered quality management processes in the Kawasaki shipyards, and in the process became one of the founding fathers of modern management. The cause and effect diagram is used to explore all the potential or real causes (or inputs) that result in a single effect (or output). Causes are arranged according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events. This can help you search for root causes, identify areas where there may be problems, and compare the relative importance of different causes.

Causes in a cause & effect diagram are frequently arranged into four major categories. While these categories can be anything, you will often see:

- manpower, methods, materials, and machinery (recommended for manufacturing)
- equipment, policies, procedures, and people (recommended for administration and service).

These guidelines can be helpful but should not be used if they limit the diagram or are inappropriate. The categories you use should suit your needs. At SkyMark, we often create the branches of the cause and effect tree from the titles of the affinity sets in a preceding affinity diagram.

The C&E diagram is also known as the fishbone diagram because it was drawn to resemble the skeleton of a fish, with the main causal categories drawn as "bones" attached to the spine of the fish, as shown below.

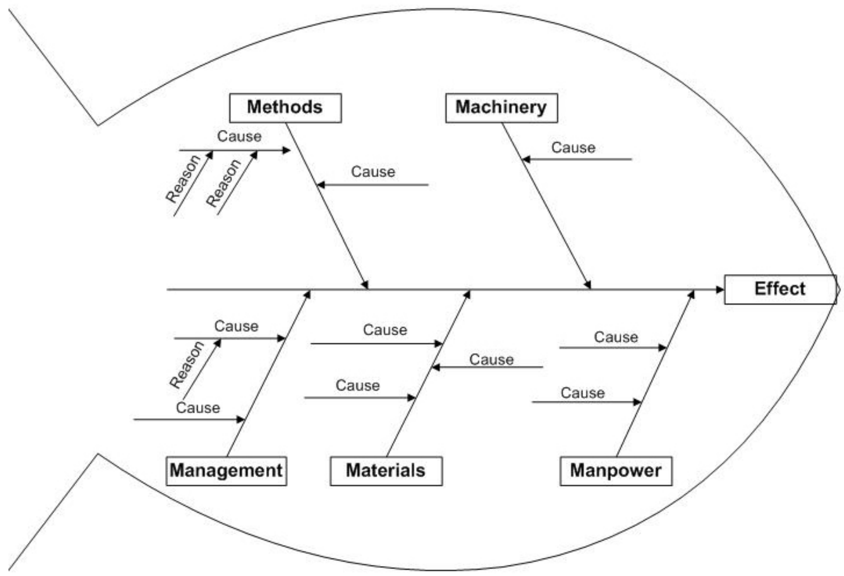


Figure 2. Fishbone Diagram

Cause & effect diagrams can also be drawn as tree diagrams, resembling a tree turned on its side. From a single outcome or trunk, branches extend that represent major categories of inputs or causes that create that single outcome. These large branches then lead to smaller and smaller branches of causes all the way down to twigs at the ends. The tree structure has an advantage over the fishbone-style diagram. As a fishbone diagram becomes more and more complex, it becomes difficult to find and compare items that are the same distance from the effect because they are dispersed over the diagram. With the tree structure, all items on the same causal level are aligned vertically.

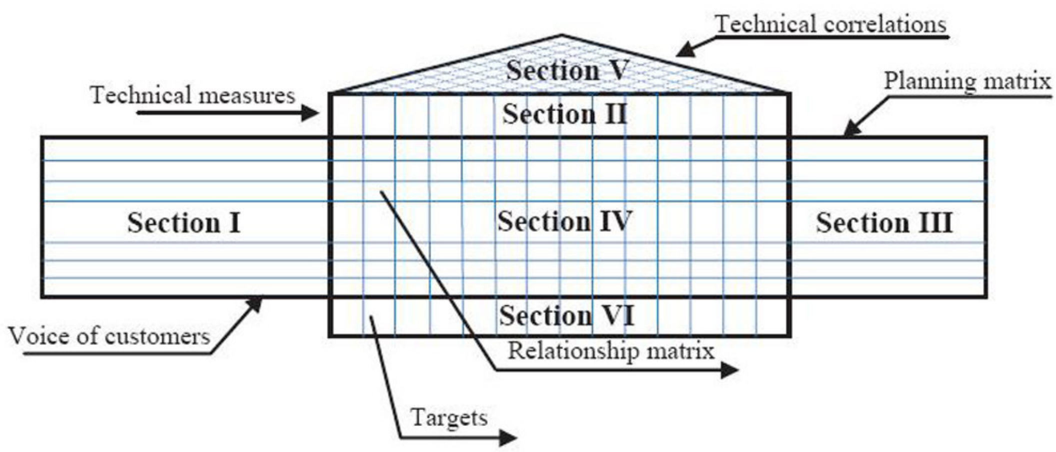
4.7.2. Analyzing The Relationships Among The Technical Attributes: Roof of The HOQ

In product design, a change in the value of one technical attribute may affect the value of one or more other technical attributes. This in turn could affect the customer requirements. It is important to figure out the relationships among the technical attributes, (Lai, et al. 2007).

4.8. The House of Quality Matrix

The HOQ matrix whose name derives from its house-like appearance is a combination of sub-matrices used to increase customer satisfaction by producing products/projects exactly demanded by the customers. The sections constituting the HOQ matrix are namely table 7.

Table 7. Basic House of Quality Matrix
(Source: Dikmen,et al. 2004)



_ Section I : Customer needs and requirements (voice of customer, VOC)

_ Section II: Technical measures

_ Section III: Planning matrix

_ Section IV: Relationship matrix

_ Section V: Correlation matrix

_ Section VI: Weights, benchmarks and targets

The best known instrument of QFD is the so-called House of Quality (HoQ). The HoQ is a matrix which analyzes customer requirements in detail and translates them into the designers' language. The traditional QFD house of quality matrix has the characteristics given in the table 7. It comprises seven main steps. The process of completing the HoQ is described by Mizuno and Akao,(Mizuno and Akao 1994).

House of Quality is a graphic tool for defining the relationship between customer desires and the firm/product capabilities. It is a part of the Quality Function Deployment (QFD) and it utilizes a planning matrix to relate what the customer wants to how a firm (that produce the products) is going to meet those wants. It looks like a House with correlation matrix as its roof, customer wants versus product features as the main part, competitor evaluation as the porch etc. It is based on "the belief that products should be designed to reflect customers' desires and tastes", (Hauser and Clausing 1988). It also is reported to increase cross functional integration within organizations using it, especially between marketing, engineering and manufacturing.

The basic structure is a table with "Whats" as the labels on the left and "Hows" across the top. The roof is a diagonal matrix of "Hows vs. Hows" and the body of the house is a matrix of "Whats vs. Hows". Both of these matrices are filled with indicators of whether the interaction of the specific item is a strong positive, a strong negative, or somewhere in between. Additional annexes on the right side and bottom hold the "Whys" (market research, etc.) and the "How Muches". Rankings based on the Whys and the correlations can be used to calculate priorities for the Hows.

House of Quality analysis can also be cascaded, with "Hows" from one level becoming the "Whats" of a lower level; as this progresses the decisions get closer to the engineering/manufacturing details.

The HoQ starts with the customer needs and the customer competitive evaluations together with the level of importance that the customers assign to their needs complemented by their complaints and the way they rate the products/services of your company against those of the competitors. These needs are translated into technical features by a relationship matrix that further deploys itself into a triangular correlation matrix and competitive technical assessments with its own set of operational goals and targets The HoQ relates simply customer requirements, technical requirements and competitive analysis. The relationship matrix of HoQ shows the correlation between the customer requirements and the technical features so it is also called as the "planning matrix". It is crucial that this matrix be developed carefully since it becomes the basis of the entire QFD process, (Ozdağoğlu, et al. 2005).

CHAPTER 5

THE IMPLEMENTATION OF QUALITY FUNCTION DEPLOYMENT (QFD) AND ANALYTICAL HIERARCHY PROCESS (AHP) IN PRODUCT

5.1. The Product: ‘Vıtra Potsink’

In this study, we examined a sink design labelled as *potsink*, designed by an internationally well-known Turkish designer for a local ceramic firm which has a distinguished share in international market. This product has a special user profile because of its unique design concept. The form and the material chosen for the *potsink* recall the design concepts of ecology, recycling and durability with its strong form connonation with traditional pot design. The inspiration point for the design is not in any way related with today’s conventional sanitary equipments; instead it brings a timeless design object into play- a pot, which is used for various purposes, through centuries and accross cultures. The design object manifests itself as domestic and traditional against the white, smooth contours of standardized modern hygenic equipments.

Potsink has two different usage styles. These are assembling to the wall and the bench. These are shown in figure 3 and figure 4 and the dimensions and specifications of the design object is given as below:

Flowerpot accesory weight: 2kg
Flowerpot basin weight : 5kg
Flowerpot accesory : 14cm
Flowerpot basin : 37cm

Figure 3. Vitra Potsink, Applied to The Wall
(Source: Eczacıbası Vitra 2008)

Figure 4, Vitra Potsink usage on bench
(Source: Industrie Ceramiche 2008)

Figure 5, Vitra Potsink Innerside Perspective
(Source: Eczacıbası Vitra 2008)

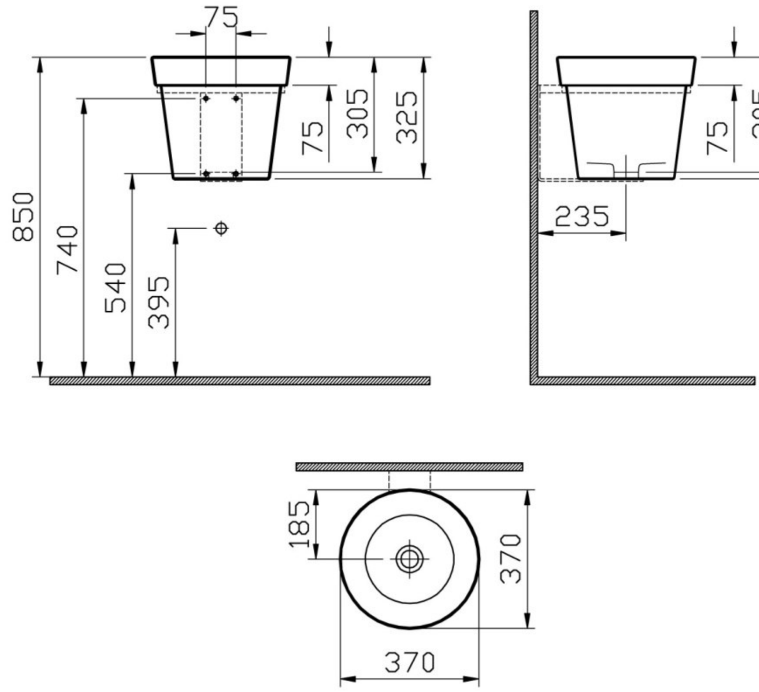


Figure 6, Technical Drawing of Montaged to the Wall
(Source: Eczacıbasi Vitra 2008)

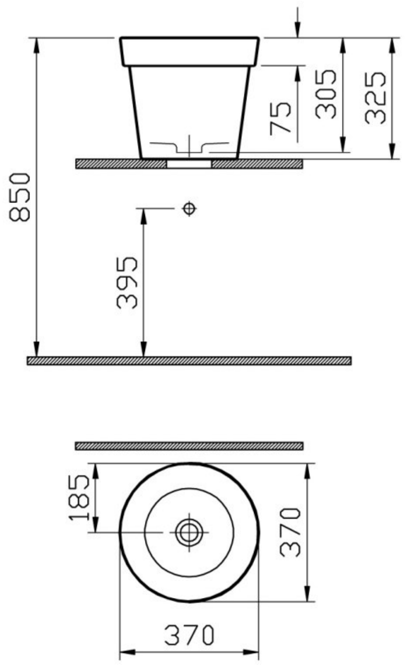


Figure 7, Technical Drawing of Montage on The Bench
(Source: Eczacıbasi Vitra 2008)

5.2. Target of the project

Ceramic production includes a gruelling process. It means that optimizations may be quite difficult and may cost a lot for the company. However, when QFD is a part of the production process, it supplies the company with more customer satisfaction and sales guarantees. In this study, we choose the QFD method provided by Yoji Akao to examined a ceramic washbasin to analyse the performance of QFD. By this we aim at proving the success of the method and how it works in the ceramic industry. We also intend to offer some solutions for optimizations.

5.3. Gemba: The Source of Customer Data

The Gemba is where the product or services becomes of value to the customer, that is, where the product actually gets used, (Mazur 1996). In Gemba, we determined who is actually our customer and what their problems and needs about the product.

5.4. Determining Key Customers

In this study, the target customer profile defined as well-educated middle and high income people who are in different age and sex groups. The people who were asked to join the questionnaire are selected along the ones who follow the current design trends and experience radical design ideas. The table 8 presented below shows a sample of the interviewed people, the ratio is 6 out of 40. Additionaly this, you can see whole customer profiles in appendix-A.

Table 8. Customer Profiles

Customers	Occupation	ge
1.Customer	IT Expert	9
2.Customer	Physician	2
3.Customer	Teacher	9
4.Customer	Economist	7
5.Customer	Architect	3
6.Customer	Housewife	3

5.5. Determining The Customer Needs –Voice of Customer (VOC)

In this step, we classified some information concerning the product before the interviews, observations and data analyses because we had to make sure that we went beyond the obvious statement made by the customers, in order to create new solutions about the product. Then we noted these needs as independent of the solution. During these interviews in the Company's local store, we discussed about the product with the customers. We asked them some classified questions, such as: the design, usage, cleaning and the combination of the product with other sanitary equipment to find out about their main needs. In the local store the customers observed and examined the product. Then they underscored some main needs and specified some problems based on their previous experience. At this stage of the study, Raw customer expectations were transformed into benefits and then into technical features. In this way, the transformation of Voice of Customers (VOC) into Voice of Engineer (Functional requirements and features) was provided.

Table 9. Features and Benefits

FEATURES	BENEFITS
Sizes	I do not want that the product does not splash water around
	I want to clean the product easily.
Glaze Indirgients (içeriği)	I want that the product does not keep bacterias and stain
Chrome plated	I want that supporter handles save their brightness
Durability	I want to use long time.
Design Idea	I want a good appearance
	I want that liquid soap does not pour on floor.

After that we discussed on which needs could be implemented, missing parts and other possibilities. According to these informations, we classified main needs, and determined the importance weight of customer requirements. In the end we reduced the list to a clear basic form. Following is the list:

1. The product should not splash water: the customers agree upon this common situation. Naturally, they do not want their bathroom floor to get wet. They think that the product does not have enough capasity to solve water splashing problem.
2. Easy cleaning: as sinks in perpendicular shape get dirty more easily compared to the oval ones, it is more difficult to keep them clean. ‘Potsink’ does have a perpendicular shape which makes “easy cleaning” one of the common need pointed out by the customers.
3. Good appearance: this requirement is really important for the customer. Generally customers prefer aesthetic, smart and a bit distinguished designs for a sink. However the customers agree upon the potsink’s design is pretty good but at some points there are some negations in mostly ergonomic parameters, which caused difficulties in using.
4. It Should not keep bacterias and stain: hygiene is another customer need. Due to the stains and bacterias, customers use chemical cleaning agents, and these are

not only harmful for human body but also expensive. For this reason, they should be used as little as possible.

5. Liquid soap should not drop on the floor: according to the customers' experience in such designed sink the liquid soap drops on the floor. A solution for this problem is a requirement made by the customers.

6. Supporter handles should save brightness: in this product, supporter handles are made of chrome plating but this material's durability is limitted and it may rust in a short period of time. And the customers want to have bright handles.

7. Long term using: using a sink for a long time with satisfaction is another customer need. Customers moslty prefer to use a sink for a long time due to financial reasons. It is also not practical to get new one each time as it is a building material. So it should be durable and it should have a good design.

5.6. Priority Needs- Analytic Hierarchy Process (AHP)

The customer needs on the hierarchy diagram must be quantified, and then prioritized by actual customers so we know which needs are important. For this purpose, we followed five steps.

5.6.1. Determining Criterias

In this step, we determined the decision problem. This process consist of two stages which include how many criterias effect the problem and how they affected by other situations. In this study, main criterias were symbolized with **m** and other criterias were symbolized with **n**. This classification is important to get consistent results.

5.6.2. Comparison Matrix

This matrix is a square matrix which is nxn dimension. You can see that in tablex.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

In the matrix, components which are on the comparison diagonal, are numbered as '1' because in this situation, same criterias are compared with eachother. When different customer requirements are compared with each other, we use a numeric scale which you can see in table 10.

Table 10. The fundamental scale for pairwise comparisons
(Source: Saaty 1995)

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

After this, we numbered all customer requirements one by one. You can see this process in table 11.

Table 11. AHP Plan Matrix

	Water should not splash water	Easy Cleaning	Good Appearance	It Should not keep bacterias and stain	Liquid soap should not pour on floor	Supporter handles should save brightness	Long term using
Water should not splash water	1	3	3	5	1	1/3	3
Easy Cleaning	1/3	1	1	3	1/5	1/7	1
Good Appearance	1/3	1	1	3	1/5	1/7	1
It Should not keep bacterias and stain	1/5	1/3	1/3	1	1/7	1/9	1/3
Liquid soap should not pour on floor	1	5	5	7	1	1/3	3
Supporter handles should save brightness	3	7	7	9	3	1	7
Long term using	1/3	1	1	3	1/3	1/7	1
	6,2	18,3	18,3	31,0	5,9	2,2	16,3

In this table an integer means the row entry is more important than column entry. When the column is more important we use inverse. For instance, if we compare first customer need 'The product should not splash water' with second requirements 'Easy cleaning', first need has moderate importance than second one. For displaying this comparison, we use 3 for second component in horizontal and 1/3 for second one in vertical.

After this, we formulated this process and determined all requirements by using a formule which is demonstrated as;

$i=1$

$j=3$

$$a_{ji} = \frac{1}{a_{ij}}$$

5.6.3. Percentage Calculation

In this matrix, each requirements have their own logical importances. However when we want to see their importances in a whole, we should see each requirements percentages. For this purpose, we use column vectors and we developed ***B*** vector which consist of *n* items and *n* components. You can see this vector in following.

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ . \\ . \\ . \\ b_{n1} \end{bmatrix}$$

For calculating this vector, we used this formule:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

For instance, if we want to calculate $\boldsymbol{B}_1$ vector;

$$A = \begin{bmatrix} 1 & 3 & 3 & 5 & 1 & 1/3 & 3 \\ 1/3 & 1 & 1 & 3 & 1/5 & 1/7 & 1 \\ 1/3 & 1 & 1 & 3 & 1/5 & 1/7 & 1 \\ 1/5 & 1/3 & 1/3 & 1 & 1/7 & 1/9 & 1/3 \\ 1 & 5 & 5 & 7 & 1 & 1/3 & 3 \\ 3 & 7 & 7 & 9 & 3 & 1 & 7 \\ 1/3 & 1 & 1 & 3 & 1/3 & 1/7 & 1 \end{bmatrix}$$

$\boldsymbol{B}_1$ vector, $\boldsymbol{b}_{11}$ eleman is calculated as;

$$\mathbf{b}_{11} = 1 / 1+0{,}33+0{,}33+0{,}2+1+3+0{,}33$$
$$= 0{,}16$$

When we calculated other components of B_1 vector, it gives us ‘1’. You can see it in B_1 vector in the following.

$$B = \begin{bmatrix} 0{,}16 \\ 0{,}05 \\ 0{,}05 \\ 0{,}03 \\ 0{,}16 \\ 0{,}48 \\ 0{,}05 \end{bmatrix}$$

After we repeated this calculating with the other components, this gave C matrix which consist of *n* items *B* vector.

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{bmatrix}$$

$$C = \begin{bmatrix} 0{,}16 & 0{,}16 & 0{,}16 & 0{,}16 & 0{,}17 & 0{,}15 & 0{,}16 \\ 0{,}05 & 0{,}06 & 0{,}06 & 0{,}10 & 0{,}03 & 0{,}07 & 0{,}06 \\ 0{,}05 & 0{,}06 & 0{,}06 & 0{,}10 & 0{,}03 & 0{,}07 & 0{,}06 \\ 0{,}03 & 0{,}02 & 0{,}02 & 0{,}03 & 0{,}02 & 0{,}05 & 0{,}02 \\ 0{,}16 & 0{,}27 & 0{,}27 & 0{,}23 & 0{,}17 & 0{,}15 & 0{,}16 \\ 0{,}48 & 0{,}38 & 0{,}38 & 0{,}29 & 0{,}51 & 0{,}46 & 0{,}49 \\ 0{,}05 & 0{,}06 & 0{,}06 & 0{,}10 & 0{,}06 & 0{,}05 & 0{,}06 \end{bmatrix}$$

This calculation is also called as normalization. To normalize, we sum the elements and divide each element by this sum and multiply by 100. This is called the

Row Average of the Normalized Columns (RANC) method. This gives me percentage values of columns. We called it as W column.

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

You can see W vector in following,

$$W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix}$$

$W_1 = 1{,}155 / 7$

$=0{,}16$

$$W = \begin{bmatrix} \frac{0{,}161+0{,}164+0{,}164+0{,}161+0{,}170+0{,}151+0{,}184}{7} \\ \frac{0{,}054+0{,}055+0{,}055+0{,}097+0{,}034+0{,}065+0{,}061}{7} \\ \frac{0{,}054+0{,}055+0{,}055+0{,}097+0{,}034+0{,}065+0{,}061}{7} \\ \frac{0{,}032+0{,}018+0{,}018+0{,}032+0{,}024+0{,}050+0{,}020}{7} \\ \frac{0{,}161+0{,}273+0{,}273+0{,}226+0{,}170+0{,}151+0{,}184}{7} \\ \frac{0{,}484+0{,}382+0{,}382+0{,}290+0{,}511+0{,}453+0{,}429}{7} \\ \frac{0{,}054+0{,}055+0{,}055+0{,}097+0{,}057+0{,}065+0{,}061}{7} \end{bmatrix} \cong \begin{bmatrix} 1{,}155 \\ 0{,}420 \\ 0{,}420 \\ 0{,}196 \\ 1{,}437 \\ 2{,}930 \\ 0{,}442 \end{bmatrix}$$

5.6.4. Consistency

Even if AHP has a consistent system, results will be depended on decision maker. For this purpose, a consistency ratio (CR) must be calculated. To calculate Consistency ratio, we must determine the basic value (λ) and number of factors. For determining λ, we multiply matrix A and W. End of this step, we draw up matrix-D. You can see this calculation in following.

$$D = A\begin{bmatrix} 1 & 3 & 3 & 5 & 1 & 1/3 & 3 \\ 1/3 & 1 & 1 & 3 & 1/5 & 1/7 & 1 \\ 1/3 & 1 & 1 & 3 & 1/5 & 1/7 & 1 \\ 1/5 & 1/3 & 1/3 & 1 & 1/7 & 1/9 & 1/3 \\ 1 & 5 & 5 & 7 & 1 & 1/3 & 3 \\ 3 & 7 & 7 & 9 & 3 & 1 & 7 \\ 1/3 & 1 & 1 & 3 & 1/3 & 1/7 & 1 \end{bmatrix} \times W \begin{bmatrix} 1,155 \\ 0,420 \\ 0,420 \\ 0,196 \\ 1,437 \\ 2,930 \\ 0,442 \end{bmatrix} \cong \begin{bmatrix} 1,199 \\ 0,423 \\ 0,423 \\ 0,198 \\ 1,495 \\ 3,063 \\ 0,450 \end{bmatrix}$$

Then, we devided each D and W values to eachother and it gave me (E). When we calculate the arithmetic average, it gives me (λ). You can see this in following formules.

$$E_i = \frac{d_i}{w_i} \qquad (i = 1,2,...,n)$$

$$E_1 = \frac{d_1}{w_1} = \frac{1,119}{0,16} = 7,269$$

$$\lambda_{\max} = \frac{\sum_{i=1}^{n} E_i}{n}$$

$\lambda_{max} = 7,318$

After finding λ, we calculated consistency index (CI) as,

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

$$CI = \frac{7,318 - 7}{7 - 1} = 0,053$$

In the final step, we devided consistency index(CI) to random index (RI) which consists of standart revision values. You can see RI table 12 in following.

Table 12. Random Index (RI)

N	RI
1	0
2	0
3	0,52
4	0,89
5	1,11
6	1,25
7	1,35

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0,053}{1,35} = 0,039$$

As a result of this calculations, if CR value is under 0.10, AHP analysis is consistent. If this number is more than 0.10, it shows that there might be a calculation mistake or decision maker's inconsistency. In this situation, whole process must be repeated.

5.6.5. Importance Weights of Customer Requirements

We use importance weights of customer requirements in section-I in house of quality matrix (HoQ). To determine these weights, we sum horizontal columns and devided each one to find total value. Then we find row averages which give us percentages of requirements.

Table 13. Normalizing Customer Requirements

	Water should not splash water	Easy Cleaning	Good Appearance	It Should not keep bacterias and stain	Liquid soap should not pour on floor	Supporter handles should save brightness	Long term using								Sum	Row av.
Water should not splash water	1	3	3	5	1	1/3	3	0,16	0,16	0,16	0,16	0,17	0,15	0,16	1,14	16,24
Easy Cleaning	1/3	1	1	3	1/5	1/7	1	0,05	0,06	0,06	0,10	0,03	0,07	0,06	0,41	5,91
Good Appearance	1/3	1	1	3	1/5	1/7	1	0,05	0,06	0,06	0,10	0,03	0,07	0,06	0,41	5,91
It Should not keep bacterias and stain	1/5	1/3	1/3	1	1/7	1/9	1/3	0,03	0,02	0,02	0,03	0,02	0,05	0,02	0,19	2,78
Liquid soap should not pour on floor	1	5	5	7	1	1/3	3	0,16	0,27	0,27	0,23	0,17	0,15	0,16	1,42	20,28
Supporter handles should save brightness	3	7	7	9	3	1	7	0,48	0,38	0,38	0,29	0,51	0,46	0,49	3,00	42,85
Long term using	1/3	1	1	3	1/3	1/7	1	0,05	0,06	0,06	0,10	0,06	0,05	0,06	0,42	6,03
	6,2	18,3	18,3	31,0	5,9	2,2	16,3	1	1	1	1	1	1	1	7	100

According to Row Avarages, we determine a new scale which includes ranks betwen 1-5 of the impotrance weights of customer requirements as you see in table 14.

Table 14. Important Weights Scale

0,248		0,198	**5**
0,197		0,148	**4**
0,147		0,098	**3**
0,097		0,048	**2**
0,047		0	**1**

Strenght of relationships:

1-weakest

2-weak

3-medium

4-strong

5-strongest

After that I give their ranks to the customer requirements as you see in table 15.

Table 15. Weights of Customer Requirements' Importance Weights

Water Should not Splash Around	2
Easy Cleaning	1
Good Appearance	1
It Should not keep bacterias and stain	1
Liquid Soap should not pour on floor	3
Supporter Handles should save brightness	5
Long term using	1

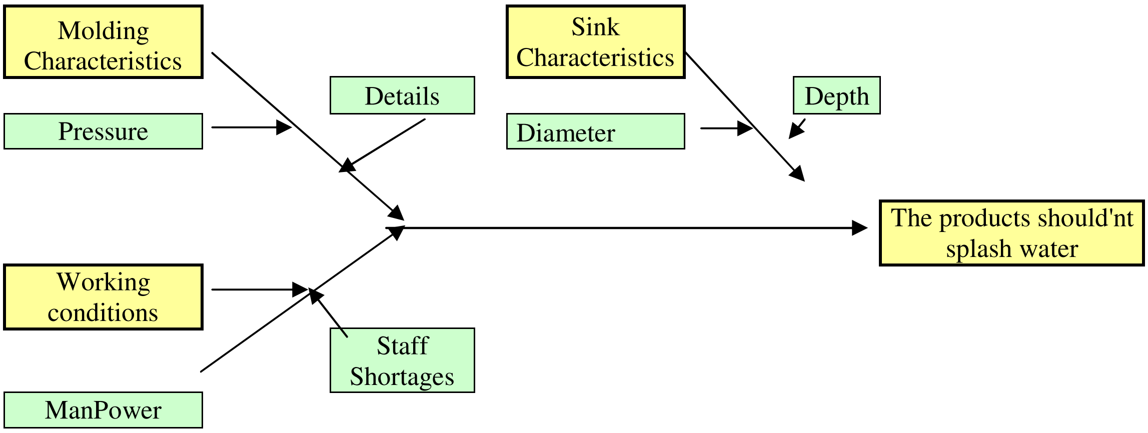
5.7. Technical Attributes

In this step, we work on tecnical attributes of the product. Technical requirements should be measurable so that we are able to determine whether customer requirements have been fulfilled. For this purpose, we started to analyse cause-reason relationship. We create a fishbone diagram to see a more detailed result and to be able to turn this result into a basic and clear technical attribute. There is a binary application between Diagram Causes and Results, either starts from Diagram Causes to results, or the other way.

The first application of us aimed at defining the real expectations of the customer, which were not necesarily explicited by themselves during the interview. The findings from this phase of the study demonstrated that one expectation could be the equivalent of another expectation in the mentioned list. For instance, while the customers pointed out non-splashing quality, they were also mentioning about easy cleaning and hygenic qualities. It is obviously necessary to increase the diameter in order to stop splashing which would in turn increase the incline and provide a smooth fall from top to bottom. This form opeartion also would provide a better solution for cleaning since there would be less perpendicular surfaces which are capable of keeping dirt.

The following stage demonstrates us that top critical expectations of the customers may demand major changes in the design which would also cause a chain raction between other technical aspects of the product or in the different phases of manufacturing process. For example, an increase in the diameter of the sink automatically modifies its volume, form, product formworks and many other technical aspects. As it can be understood easily, looking at these details and relating them to eachother will enable us to correspond to the other customer needs as well. Following is a sample diagram for this theory.

Table 16. Technical Attribute "Fishbone Diagram"



In the diagram, yellow boxes include main causes and blue boxes include details and overall which refer to an effect such as: the product shouldn't splash water.

Additionaly this diagram, we determine basic technical attribues with their brief explanations;

5.7.1. Diameter of The Washbasin

Diameter is an important component for using a washbasin in a bathroom. For this reason, product's dimensions must be in standart ergonomics. When Potsink's diameter is compared with standart ergonomics, it is shown that Potsink's diameter is more narrow. According to ergonomics, a clear space of 110cm should be available between the front of the basin and a wall or other obstruction but Potsink's diameter is just 37cm, (Aksoy, et al. 1977).

5.7.2. Depth of The Sink

Depth is another important dimension for a washbasin design. Because, the more perpendicular area in a washbasin's clean space, the more getting dirty. For this reason, depth of a washbasin must be in a standart dimension.

5.7.3. Vitrahygiene

VitrAhygiene offers public bathrooms the same excellent level of hygiene that is available in private homes. It is applicable to all ceramic sanitaryware including washbasins, WCs, urinals and bidets, as well as to acrylic bathtub and shower trays. VitrAhygiene anti-bacterial glaze is created by adding silver ions to the raw glaze before firing. The silver particles reduce bacterial growth, offering 99.9 % resistance to bacteria. Bathtubs and shower trays are made of Lucite Care acrylic plates. Developed by the British IneosAcrylics, Lucite Care plates have antibacterial additives threaded within the acrylic polymers for enhanced hygiene. The VitrAhygiene stamp on bathroom products ensures a healthy environment in every bathroom. VitrAhygiene glaze is extremely durable, and its anti-bacterial resistance is effective throughout the life-time of the product, (Potsink Product Catalog 2008).

5.7.4. Vitraclean

It is applicable to all ceramic sanitaryware including washbasins, WCs, urinals and bidets. The double glazing of sanitaryware enhances surface tension, so that water is actually repelled by the extra-smooth surface and dirt is washed along before it has a chance to dry. VitrAclean ceramic sanitaryware are easy to clean with minimal effort, eliminating the need for strong cleaning agents. VitrAclean keeps sanitaryware sparkling clean and looking their best for years. the exception of odour absorption in case of a power blackout, (Potsink Product Catalog 2008).

5.7.5. Innerside Glaze

It is a glaze which is used in sanitary ceramics. Due to the fact that, glaze is applying in high degrees about 1200C, its durable against some damages more than the other glazes. In addition to this, it seems smart with white bright appearance and safe with smooth edges.

5.7.6. Outer Glaze

Terracota is a ceramic. Its uses include vessels, water & waste water pipes and surface embellishment in building construction. The term is also used to refer to items made out of this material and to its natural, brownish orange color.

Production properties are in the fallowing;

An appropriate refined clay "grog" is partially dried and cast, molded, or hand worked into the desired shape. After further thorough drying it is placed in a kiln, or atop combustible material in a pit, and then fired. After pit firing the hot ware is covered with sand to cool, and after kiln firing the kiln is slowly cooled. When unglazed, the material will not be waterproof, but it is suitable for in-ground use to carry pressurized water (an archaic use), for garden ware, and sculpture or building decoration in tropical environments, and for oil containers, oil lamps, or ovens. Most other uses such as for table ware, sanitary piping, or building decoration in freezing environments require that the material be glazed. Terra cotta, if uncracked, will ring if lightly struck, but not as brightly as will ware fired at higher temperature, which is called stoneware. The fired material is relatively weak compared to stoneware.

Some types of terra cotta are created from grog made from recycled terra cotta. The unglazed color after firing can vary widely, but most common clays contain enough iron to cause an orange, orangish red, or brownish orange color, with this range including various colors described as "terra cotta". Other colors include yellow, gray, and pink, (Meyerowitz, et al. 1939).

5.7.7. Chrome Supporter Handles

Chrome Supporters are commonly used in sanitary ceramics. It has been resistant against corrosions for long time but some users agree that if this material is exposed to water, it is getting oxidized according to their experiences. On the other hand, it has a nice appearange with bright surfaces and for this reason, customers can prefer to use.

5.7.8. Durability

Durability of a washbasin is a necessary component in terms of safely and long time usage. There are several factors, which effect this component, such as clay's durability, glazes, design, etc.

5.7.9. Design Idea

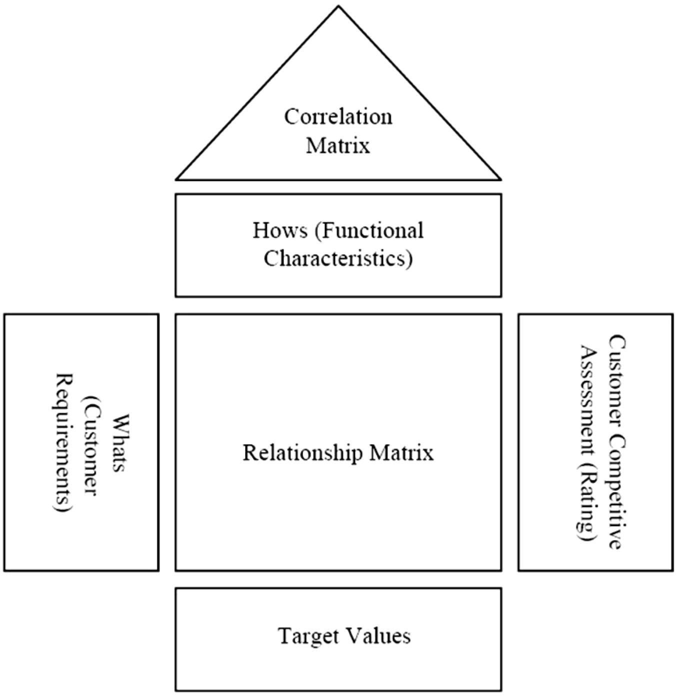
Potsink is a washbasin which a glazed terracotta washbasin shaped like a flowerpot "one of the most basic products in human history," it's designer who is a famous turkish designer Inci Mutlu, points out.

Potsink shows the actual soul, this essence of a product and puts our society's value system in question. The first flower pots from terracota for manifactured approx. 6000BC in Egypt and they are anoestros of the modern washbasins. Potsink simply adaps to flower pots into a washbasin which are both madeup of natural, ecolocig, recycable and durable clay. Thanks to this timeless and ironic form, that form can be manifactured so easily with the contemporary manufacturing machinary and so it is cost and energy efficent. And depth for the root in the classical flower pot is multi-fucntional for a washbasin. While the only glazed innerside allows easy cleaning and the drain flows through the opening hole at the bathroom just like a flower poti, (Potsink Product Catalog 2008).

5.8. House of Quality Matrix (HoQ)

In this step, we start to draw "House of quality" matrix. Fort his purpose, we determined customer requirements and their importance weights and technical attributes. And this is the turn of fixing them: customer requirements take place in the left side of the house and next to them their impontance weights take place. Technical attributes' place is top and the middle of the house you can see in table 18.

Table17. HoQ Matrix
(Source: Law and Hua 2007)



After this, we display comparison between customer requirements and tecnical attributes. For this comparison, we use a 1-3-9 scale. 1 is weakest, 3 is the middle and 9 is a strong relationship.

And also we benefit from some symbols instead of numbers. In the following, we displayed them:

⊙ Strong relationship

O Middle relationship

△ Weakest relationship

Table 18. “House of Quality” Matrix With Symbols

	Customer Requirements	**Importance Weights**	Diameter of The Sink	Depth of The Sink	Vitrahygene	Vitraclean	Innerside Glaze	Outer Glaze:Terracotta	Chrome Supporter Handles	Durability	Design Idea
1	The product shouldn't splash water		⊙	○							⊙
2	Easy Cleaning			⊙	⊙	⊙	○		○		
3	Good Appearance		△	△			⊙	⊙	⊙		⊙
4	It Shouldn't keep bacterias and stain		○	○	⊙	⊙					△
5	Liquid Soap shouldn't pour on floor		△								⊙
6	Supporter Handles should save brigtness								⊙	⊙	○
7	Long term using								○	⊙	⊙

In another table, we transformed these symbols into numbers. Then we start to draw right part of the house which includes our the values, planning values, sales points, improvement ratios, absolute weights and customer need weights related with the current product.

- Current product: this is the weight which the product has currently. Such as, for the first customer requirement “The product should not splash water” correspond to 2 in a 1-5 scale.
- Plan: this is the target weight which the company intends such as 4 point for the first customer requirement.
- Improvement ratio: this ration is calculated as plan divided by current product.

IR= P / CP

(1.customer requirement) IR = 4/2

= 2

- Sales point: traditional QFD uses the original scale sales points of 1,5 for a strong sales point and 1,2 for a weak sales point. We discuss sale points with the company's sale department.
- Absolute weight: multplying; the importance weight, imporovement ratio, and sales point gives absolute weights of the customer requirements to us.

AW = IW x IR x SP

(1.customer requirement) AW = 5x2x1

=10

- Customer need weight: the absolute weights are summed and each divided by the sum to yield a normalized customer need weight.

CNW = AW (1.) / ∑ (AW) x 100

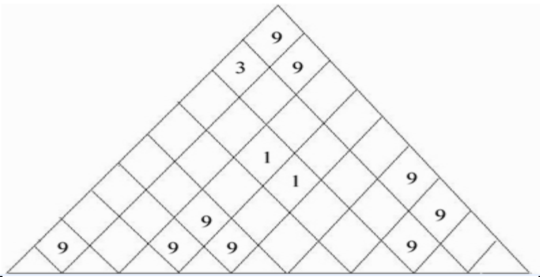
(1. customer requirement) CNW = 10 / 44 X 100

= 22

In the next step, we multiply the customer needs weight by relationship which is between customer requirements and technical attributes strengh, sum products in each column to get an absolute weight, sum those and divides each by the sum to calculate a technical attributes' weights.

The last part of the house is the roof which includes relationships between each technical attributes. We use a 1-3-9 scale in this part. These rates will be able to give us chance to think about technical optimizations. In the following table 20, we draw the house of quality matrix which includes all those informations.

Table 19. "House of Quality Matrix



	Customer Requirements	Importance Weights	Diameter of The Sink	Depth of The Sink	Vitrahygene	Vitraclean	Innerside Glaze	Outer Glaze:Terracotta	Chrome Supporter Handles	Durability	Design Idea	Current Product	Plan	Improvement Ratio	Sales Point	Absolute Weight	Customer Need Weight
1	The product shouldn't splash water	2	117	39							117	2	4	2	1,5	6	13
2	Easy Cleaning	1		58	58	58	19		19			2	4	2	1,5	3	6,5
3	Good Appearance	1	13	13			117	117	117		117	4	5	1,3	1,5	6	13
4	It Shouldn't keep bacterias and stain	1	39	39	117	117					13	5	5	1	1,2	6	13
5	Liquid Soap shouldn't pour on floor	3	6,5								58	1	3	3	1	3	6,5
6	Supporter Handles should save brightness	5							388	388	129	4	5	1,25	1	20	43
7	Long term using	1							16	47	47	2	4	2	1,2	2,4	5,2
	Absolute Weights		175	149	175	175	136	117	540	434	481	2383,22				46	100
	Technical Char. Wt.		7,4	6,2	7,4	7,4	5,7	4,9	23	18	20	100					

CHAPTER 6

CONCLUSION

The biggest costs in the ceramic industry are constituted by labor and molding. Any changes in design after the post production process requires all the moldings at the production level to be altered which would bring additional labor costs as well as risk the quality of the products after the remediation. For this reason, the inclusion of the QFD in the production process will have a significant effect in decreasing the production process to a minimum, decreasing the costs reserved for remedies, and gaining a more advantageous position in sales by satisfying the customer expectations.

For these aims, we applied QFD method to 'Potsink' in some ranks. We can itemize this process in four ranks to explain the situation more clear.

The first item was determining the customer requirements. In this step, we determined key customers, we got provide a meeting between customer and product. Then we learned customers' opinions and classified these informations according to more popular needs and expectations which were determined by the majority.

The second item was application anaylitic hierarchy process AHP to understand hierarchic order between customer requirements. During this process, we determined some criterias which have an important rules for saling advantages. These criteras were design, cost and quality. After this, we tried to increase inferior criteras to supply consistency of the analysis.

In the third step, we had already leraned the customer needs' weights in previous step. According to these informations, we determined technical attributes which are compared with customer needs and put them into the house of quality (HoQ). Also we determined relationship between each technical attributes in roof of HoQ.

The last step includes analysis of results which we get from HoQ. As a result of whole process, we find out some results. These results demonstrate that some properties of the product can be optimizated.

In conclusion, we considered datas of HoQ and found these results:

- Absolute weights which was calculated with customer requirements and plan section is shown in the following table 20.

Table 20. Percentages of Customer Requirements

	Percentages of Customer Requirements	%
1	The product shouldn't splash water	13
2	Easy Cleaning	6,5
3	Good Appearance	13
4	It Shouldn't keep bacterias and stain	13
5	Liquid Soap shouldn't pour on floor	6,5
6	Supporter Handles should save brigtness	43
7	Long term using	5,2

When we analyse percentages of the customer requirements, we observed that customers may get suspecious whether they want to buy the product or not. Because, they thought that chrome handles might not save brightness for a long time. According to the highest percentage (%43) of this customer need which is calculated with plan section, it is seen that the result is consistent. In the following of this calculation, we added technical attributes into the HoQ matrix. At the end of this, we get percentages of combination of technical attributes and customer requiremetns:

Table 21. Percentages of Combination of Tecnical Attributes and Customer Requirements

	Technical Attributes	%
1	Diameter of the Sink	7,4
2	Depth of the Sink	6,2
3	Vitrahygiene	7,4
4	Vitraclean	7,4
5	Innderside Glaze	5,7
6	Outer Glaze: Terracotta	4,9
7	Chrome Supporter Handles	23
8	Durability	18
9	Design Idea	20

When we observed datas in table 21, we saw that the highest rank belong to chrome handle with %23. This rank supports that the most useful optimization can be applied on this requirement.

The roof of HoQ helps to construct relations between other technical attributes, which effect other attributes in a positive way. For instance, when we change chome handle's material, it increases durability of product. We can see this relation with the number of 9 which is the top rank.

Another result of the survey is determining 'design idea'factor's importance. When we checked the table 21, we saw that percentages of design idea is %20. As we can see easily, this is another higher rank in order. Additionally this, the roof of the HoQ shows that design idea is in a strong relationship with diameter and depth of the product, too. It means that if we would change the design, diameter and depth would changed too. In this situation, when we cheked the table again, we can see that diameter and depth of sink have importances which have %7,3 and %6,3 percentages.

If we apply an optimization process to the product, we should sum this ranks to determine absolute weight of the customer requirement. You can see this calculation in the following:

Absolute Optimization Weight= % Diameter of the Sink+% Depth of the Sink+% Design Idea

AOW= %20+%7,3+%6,3 = %33,6

This rank shows that if we optimizate the design of the product, this optimization would be more useful than the others for both customers and the company. Because, the HoQ matrix gives a consistent scale which two datas can associated in the matrix.

In this research, I pointed out some properties which have high values in customers' perspective. In deed, if there is a need, the company has to provide this expectations. When we apply QFD method in the production process, it supplies the maximum yield for the company as well as the customer.

As a consequence, according to the results of this analysis, potential optimizations can be itemized as follows:

1. **Proportional optimization:** Although the original form of the pot has certain proportions that can hardly be changed, a dimensional redesign of the product is still possible by increasing the diameter at the upper periphery. While doing this, the diameter at the lower periphery should be kept fixed in order not to enlarge the overall dimension of the product.

2. **Material optimization:** The chrome supporter handles cause a weakness in design from the point of easy maintenance. The chrome material can be interchanged with stainless steel accessories which may help to increase the performance of the product.

3. **Additional accessories:** A soap bar is still one of the indispensables for the majority of Turkish customers, without exception. This disadvantage of the product also became apparent as the results of our QFD application. In addition to this, the present form of the product is inspired by the purity of traditional cleaning rituals. The design conveys purity by using a minimum number of additional accessories and terracotta material . For this reason, adding a separate soap dish may disturb the minimalist approach of the original design. However, the original design includes an optional accessory consisting of a smaller size pot which is intended to function as a real pot. This accessory can be optimized to contain a traditional soap dish.

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APPENDICES

APPENDIX A
LIST OF CUSTOMERS
WHO PARTICIPATE IN THE STUDY

	Name and Surname	Age	Occupation
	First Group:		
1.	Metin YILDIZ	27	Economist
2.	Zehra TANOL	29	Instructor
3.	Bora ENGIN	25	IT Expert
4.	Yusuf YILMAZ	39	Economist
5.	İlker CANKARA	31	Engineer
6.	Arife DUYAR	53	Housewife
7.	Hilmi DURNAOĞLU	25	Interior Designer
8.	Mustafa YILMAZ	32	Engineer
9.	Nergis DOGAN	27	Biologist
10.	Zehra TANOL	29	Instructor
11.	Volkan OYAN	27	Instructor
12.	Nevriye KARAKAYA	26	Chemist
13.	Seden SEVENOGLU	30	Physiologist
14.	Duygu KAPSIZ	24	Chemist
15.	Mehmet Ali ALBAYRAK	40	Engineer
16.	Naim CEYLAN	43	Physician
17.	Tarık DIKBASAN	27	Engineer
18.	Tufan DALKILIC	39	IT Expert
19.	Emre YILMAZ	24	Engineer
20.	Gülşah YETKIN	24	Teacher
21.	Gökhan ERGENC	40	Engineer
22.	Barış KOCYIGIT	32	Insurance Broker
23.	Nurhayat FILIZ	51	Retired Engineer
24.	Nusret BARLAK	60	Retired Teacher

25. Zuhal YILMAZ	55	Retired
26. Gokhan ONLU	28	Economist
27. Dincer KARAKOYUN	28	City Planner
28. Yonca BASSOY	30	Biologist
29. Sultan BASARAN	34	Instructor
30. Nihal OLCER	60	Housewife
31. Basri Ivit	63	Architect
32. Neslihan KALELI	25	Artist
33. Şerafettin DEDEOGLU	28	Graphic Designer
34. Ceyda OKTEM	28	Designer
35. Gökhan ERBAS	27	Graphic Designer