Sıdıka Esra BAŞLIGİL YIRCALI

M.S. Thesis In Industrial Engineering

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AN APPLICATION OF PROCESS MANAGEMENT AND PROCESS IMPROVEMENT

by

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Sıdıka Esra BAŞLIGİL YIRCALI

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

_____
Assist.Prof.Dr.Ali TÜRKYILMAZ
Head of Department

This is to certify that I have read this thesis and that in my opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

_____
Assist.Prof.Özgür UYSAL
Supervisor

Examining Committee Members

Prof.Dr.Selim ZAİM _____

Assist.Prof.Dr.Özgür UYSAL _____

Assist.Prof.Dr.Ömer Fahrettin DEMİREL _____

It is approved that this thesis has been written in compliance with the formatting rules laid down by the Graduate Institute of Sciences and Engineering.

_____
Assoc.Prof.Nurullah ARSLAN
Director

Date
May 2011

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Supervisor: Assist. Prof. Dr. Özgür UYSAL

ABSTRACT

This study has been applied in an environment where Value Stream Mapping (VSM) and Quality Function Deployment (QFD) concepts are other than production, in a Maintenance, Repair and Overhaul (MRO) Company, which operates in aviation sector. With this purpose, first of all customer requests have been determined by Value Stream Mapping study. Then, in order to determine the relationship between customer requests and technical characteristics Quality Function Deployment has been applied. In this respect related correlation matrixes have been composed and final house of quality created. Thus, the priority customer requests and technical features have been determined and the results have been reported in order to provide the customer satisfaction.

Keywords: VSM, QFD, MRO

ÖZ

SÜREÇ YÖNETİMİ VE SÜREÇ İYİLEŞTİRİLMESİ ÜZERİNE BİR UYGULAMA

Sıdıka Esra BAŞLIGİL YIRCALI

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Tez Danışmanı: Yrd.Doç.Dr.Özgür UYSAL

ÖZ

Bu çalışma Değer Akış Haritalama (Value Stream Mapping (VSM)) ve Kalite Fonksiyon Yayılımı (Quality Function Deployment (QFD)) kavramlarının havacılık sektöründe faaliyet gösteren bir Bakım, Onarım ve Revizyon (Maintenance, Repair and Overhaul (MRO)) şirketinde uygulamasıdır.Bu amaçla, öncelikle Değer Akışı Haritalama çalışması ile müşteri istekleri belirlenmiştir. Daha sonra müşteri istekleri ile teknik karakteristikler arasındaki ilişkinin belirlenmesi için Kalite Fonksiyon Yayılımı uygulamasına geçilmiştir. Bu bağlamda, ilgili korelasyon matrisleri oluşturulmuş ve nihai kalite evi ortaya çıkarılmıştır. Böylece, müşteri memnuniyetini sağlamak için şirketin dikkate alması gereken öncelikli müşteri istekleri ve teknik özellikler belirlenmiş ve elde edilen sonuçlar rapor edilmiştir.

Anahtar Kelimeler: VSM, QFD, MRO

DEDICATION

To my husband, my son and my parents

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LIST OF SYSMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION

AACSB	American Assembly of Collegiate Schools of Business
AHP	Analytic Hierarchy Process
AIW	Accelerated Improvement Workshop
ALLSTAR	Aeronautics Learning Laboratory for Science Technology and
AOG	Aircraft on Ground
APU	Auxiliary Power Unit
C\T	Cycle Time
CR	Customer Requirements
CSM	Current State Map
CTQ	Customer Standards
DGCA	Directorate General of Civil Aviation
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FSM	Future State Map
HOQ	House of Quality
JAA	Joint Aviation Authorities
JAR	Joint Aviation Regulations
JIT	Just-In-Time
L\T	Lead Time
MBA	Master of Business Administration
MFD	Manufacturing Division

MHRS	Man Hours
MRO	Maintenance, Repair and Overhaul
NVA	Non-Value-Added
OEM	Original Equipment Manufacturers
PDCA	Plan-Do-Check-Act
QFD	Quality Function Deployment
R\ T	Run Time
RAR	Repair Action Report
RMA	Repair Material Authorization
RO	Repair Order
ROI	Return of Investment
RUSF	Resource Utilization Support Fund
S\T	Setup Time
TPM	Total Productive Maintenance
TQM	Total Quality Management
VOC	Voices of Customer
VSM	Value Stream Mapping
WIP	Work-in-Process

CHAPTER 1

INTRODUCTION

In this global world companies that cannot create a difference both in manufacturing and service sectors and those that cannot offer technological and superior service have faced with going bankrupt.

Rapidly developing technology has brought with it a rapid change to the business life. This caused an intensive competitive environment and the companies have had to keep up with change in order to survive.

In today's competitive conditions customer-oriented thinking is a requirement for the companies that want to be one step ahead of their competitors. The companies are to be able reach customer's and request dissatisfaction by surveys, etc. But they are not be able to translate this request dissatisfaction into the engineering language and reflect them to the processes. At this point the importance of Quality Function Deployment and Value Stream Mapping which provide understanding of customer requests and using for production/service is understood well.

The MRO companies have had to develop new methods as soon as possible in order to survive in the more competitive market and to satisfy the expectations effectively. The MROs, which serve Workmanship, Material, Turn Around Time, Performance and Quality together in the best way for their customers, become the focus of interest.

While it seems that some of the methods are difficult to adapt in an MRO Company, others not Value Stream Mapping and Quality Function Deployment methods can be applied to an MRO Company. MRO side of the company also needs to gain a competitive advantage.

This study addresses the application of Value Stream Mapping (VSM) and Quality Function Deployment (QFD) techniques to a non-manufacturing industry – a

maintenance, repair and overhaul (MRO) company. The purpose of the study is to evaluate testing and measuring devices on the domestic and abroad calibration, repairing and shipping processes using by VSM and QFD techniques, to propose new process and present a living sample on the domestic and abroad calibration, repairing and shipping, to suggest ways to reduce lead-times and non-value added time minimized and to determine priority customer requests.

For this purpose the study consists of 5 Sections.

First chapter is an introduction to the link between VSM and QFD. The second chapter is about Literature Survey. The third chapter gives a basic knowledge about The Aviation Industry and The Maintenance, Repair and Overhaul (MRO) Sector. The fourth chapter is about implementations of Value Stream Mapping and Quality Function Deployment in Calibration Factory. The Results and Conclusion are given in the last chapter.

Applications of VSM and QFD methods provide a lot of benefits, such as satisfying expectations of customers with the minimal change of design, serving production for the market in a little while, high customer's satisfaction, increasing and developing the relation between sections, developing teamwork, etc. At the same time, because of the fact that the companies are be able know the situations of their competitors in the market with VSM and QFD methods they can benefit from the opportunities and advantages. This situation provides superiority in competition. The efforts for application of VSM and QFD approaches in Turkish companies continue like in the whole world

Another purpose of this study is to integrate of Value Stream Mapping and Quality Function Deployment in order to highlight the effectiveness feature of Value Stream Mapping. It is expected that use of Value Stream Mapping and Quality Function Deployment methods will create a different viewpoint for academic literature and business owing to the fact that it is a new application in literature. At the same time another purpose of this study is to contribute for the local literature, which is inadequate in our country about VSM and QFD, and to survey of VSM and QFD applicability in a MRO company.

For the theoretical part of the study, it has been benefited from local and foreign resources about the subject. Mutual conversations with customers, personals and managers of MRO Company have been had for the application part of the study.

As a result, operating companies want to find financial solutions in the short run because of their financial difficulties. However, the benefits of VSM and QFD are to be successful in the long run, to provide customer satisfaction and continuity, to reduce costs and to increase the volume of the production.

CHAPTER 2

LITERATURE SURVEY

2.1 VALUE STREAM MAPPING (VSM)

The use of Value Stream Mapping (VSM) has been attributed to the cause of much of the success that Toyota of Japan has had since the 1980's1. Developed during the work conducted by Taiichi Ohno at Toyota in the 1960's and 70's, at its basic level VSM is a systematic methodology to identify wasted time and actions in a manufacturing process. In more recent times VSM it has been used to re-engineer businesses because it identifies unnecessary effort and resources to permit simplification and streamlining of operations processes (Sondalini, 2009).

Value Stream Mapping (VSM) is a visualization tool oriented to the Toyota version of Lean Manufacturing (Toyota Production System). It helps to understand and streamline work processes using the tools and techniques of Lean Manufacturing. The goal of VSM is to identify, demonstrate and decrease waste in the process. Waste being any activity that does not add value to the final product, often used to demonstrate and decrease the amount of 'waste' in a manufacturing system. VSM can thus serve as a starting point to help management, engineers, production associates, schedulers, suppliers, and customers recognize waste and identify its causes. As a result, Value Stream Mapping is primarily a communication tool, but is also used as a strategic planning tool, and a change management tool. Toyota have been benefiting since 1940's, from Material and Information Flow Mapping (Value stream mapping). Taiichi Ohno (1988) could not see waste at a glance (especially across a geographical area). He developed Material and Information Flow Mapping (VSM) as a standard method for mapping the flows visually and it became the standard basis for designing improvements at Toyota - as a common language. It became one of their business planning tools. VSM is now utilized throughout the world, in many businesses to strategically plan and it is the starting point to any lean transformation and implementation (Ramesh et al., 2008).

In Taiichi Ohno's words - "All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non-value-added wastes." (Ohno, 1988) It is useful to explain the meaning of several key concepts used in VSM. These are: what is meant by a process, what waste is, what is meant by 'flow', what constitutes value-adding, along with what is needless non-value-adding and what is necessary non-value-adding (Sondalini, 2009).

Value stream mapping is a visual representation of the material and information flow of a particular product family (Tapping, Luyster & Shuker, 2002). Value stream mapping consists of the creation of a current state map and a future state map. The current state map charts the present flow of information and material as a product goes through the manufacturing process. Its purpose is to help understand how a product currently flows. The future state map is a chart that suggests how to create a lean flow. The future state map uses lean manufacturing techniques to reduce or eliminate wastes and minimize non-value added activities. The future state map is used to help make decisions and plan future process improvement projects. Value stream mapping was the tool used to map the processes and create a possible scenario to reduce lead-times and increase throughput. The main source for providing the steps used to create the maps was the book Value Stream Management (Tapping, Luyster & Shuker, 2002). The researcher determined that the information in the book could provide the tools to create useful and informative maps. (Carr, 2005)

One of the primary lean tools that was found in the literature and has been effectively used in evaluating non-value added activities is VSM. It is a tool that helps in visualizing a system by the representation of information and material flow. It also creates a common language about a process, by which purposeful decisions can be made to eliminate the non value adding activities. Seven different VSM tools namely, big Picture mapping (Rother and Shook, 1999), supply chain response matrix (Hines, Rich and Jones, 1997), production variety funnel (New, 1974), quality filter mapping (Hines and Rich, 1997), demand amplification mapping (Hines and Taylor, 2000), decision point analysis (Hines, Rich and Jones, 1997) and physical structure mapping (Hines and Rich, 1997) were reviewed; however none of them directly correspond to the maintenance operations and hence cannot be applied "as is". This clearly illustrates

the uniqueness of this paper, wherein for the first time ever a value stream map is introduced specifically for measuring maintenance operations (Kannan et al.,2007).

The aim of VSM is to switch from batches and push systems to pull system and continuous flow (Lovelle, 2001; Rother, 2004; and Womack, 2006). Also, Tapping (2002) calls attention to identifying the production process, the communication between departments, the bottlenecks and the all types of waste (Caballero, 2006).

Taiichi Ohno (1988), Womack et al (1990), Womack and Jones (1998, 2005), Daniel. T. Jones (2006), Rother and Shook (1999), and Peter Hines and Nick Rich (1997) have studied the implementation of Value Stream Mapping effectively. Shingo (1989) has discussed the strategies for the effective implementation of Value Stream Mapping in a wood industry. He also opines that loops can be formed to identify the similar processes and these loops will be helpful in identifying the non value activities in a systematic manner. He has suggested the ways to eliminate non value added activity and proposed measures to increase the Value added ratio. In order to attain noteworthy improvements the Zayko, et.al (1997) have decided to use value stream mapping to visualize the entire flow and select lean tools that yielded maximum benefits. Hines and Rich (1997) have opined that, the value stream is "the specific activities within a supply chain required to design order and provide a specific product or value". New (1993), and Jones et.al (1997) and other researchers developed individual tools to understand the value stream. VSM extends guidance for improvements in the process, identifies the need to improve workflow and finally shows avenues to reduce waste. Womack and Jones (1998) and Moore (2006) have stated that, the organizations of many types are implementing lean manufacturing, or lean production, practices to respond to competitive challenges. They have mentioned that lean initiatives can be taken up in the fields of automotive sector, aerospace, and consumer goods industries around the world. Moore has discussed various implementation tools of Lean Manufacturing, which can be incorporated in the industries (Ramesh et al., 2008).

Rother (1998) affirms that the main properties of VSM fulfill the utility requirements of a manufacturing redesign technique. For his part, Pavnahskar (2003), in his categorization of lean techniques, also highlights the great potential of VSM to improve production systems (Serrano et al., 2006).

Rother and Shook (1999) have discussed that Value Stream Mapping (VSM) is used to define and analyze the current state for a product value stream and design a future state focused on reducing waste, improving lead-time, and improving workflow. The use of VSM appears to be increasing, particularly since the publication of "learning to see" by Rother and Shook (1999). One of the unique characteristics of VSM in comparison with other process analysis techniques is that one map depicts both material and information flow that controls the material flow. The focus of VSM is on a product "value stream" (all actions required to transform raw materials into a finished product) for a given "product family" -- products that follow the same overall production steps (Ramesh et al., 2008).

Rother and Shook (1999) have published a workbook in value stream mapping (VSM); whish is an important source of knowledge for Hydro Automotive Structures. According to Hines & Taylor (2000, p. 21) VSM is a tool barrowed from Toyota where it is denoted "Big Picture Mapping". Rother and Shook (1999, p. 3) limits the focus of value stream mapping to the "door-to-door" production flow inside a plant. Both the material and information flows have to be considered, and the mapping address one product family at time. The object in Lean manufacturing is to get one process to make only what the next process needs when it needs it (Bo Terje Kalsaas, 2002).

Abbett and Payne (1999) have discussed the application of value stream mapping in an aircraft manufacturing unit. They have developed the current and future state maps with the objective of reducing lead time according to customer's requirements (Ramesh et al., 2008).

The principles are also recognized by Hines and Taylor (2000) who make the plan for implementation of the lean thinking trough the concept of analysis and mapping techniques. They divided it into six steps: understanding waste, setting the direction, understanding the big picture, detailed mapping, getting suppliers and customers involved and finally checking the plan fits the direction and ensuring buy-in. These previous lines point the concept of VSM which is called "big map" from Toyota Company. Lovelle (2001) and Seth and Gupta (2005) defines VSM as a tool to understand the material and information flow that links the lean initiatives. The value stream are part of the value added activities and non value added activities. Also, the VSM looks to increase the flow from the information and material flow. Tapping

(2002) highlights that value stream management seeks to “treat employees as human fixed assets” (Caballero, 2006) .

Doolen et al. (2002) have extended the applications of lean production techniques in the electronics manufacturing perspectives. Hyer (2002) has implemented Lean manufacturing in the office service and administrative processes. Yang-Hua and Valandeghem (2002) describe, Value stream mapping as a mapping tool that is used to describe supply chain networks. It maps not only material flows but also information flows that signal and control the material flows. The material flow path of the product is traced back from the final operation in its routing to the storage location for raw material. This visual representation facilitates the process of lean implementation by helping to identify the value-added steps in a value stream, and eliminating the non-value added steps / waste (muda). McDonald et.al (2002) have used simulation techniques for the high-performance motion control products manufacturing system to demonstrate that, simulation can be a very crucial tool in assessing different future state maps. They demonstrate that simulation can provide and examine different scenarios to complement those obtained from future state mapping. The value stream mapping was extended in the field of aircraft manufacturing also (Ramesh et al., 2008).

Value stream management is an organization technique for planning, managing, implementing, sustaining and linking lean initiatives to activities of the company by taking and analysing data. (Tapping, 2002) Following these lines, Özkan, Birgün, Kılıçoğulları, and Akman, (2005) define value stream management as a tool that helps the workers to recognize the waste and build up a future state to reduce it. Tapping (2002) points out that the identification of the waste can identify the value from your customer and the value stream and eliminate any type of waste presented during the production of the products. Womack and Jones (2003) propose a similar view and present this VSM as the first tool to reach lean thinking. Womack and Jones (2003) propose a similar view and present this VSM as the first tool to reach lean thinking. Also, Womack (2006) mentions that the managers complaint that it is so hard to focus on each product and each customer in VSM (Caballero, 2006).

Sullivan et al. (2002) also used VSM in a manufacturing environment for making an investment decision by using a cellular approach and reducing lead time. Bushell and Shelest (2002) applied VSM in healthcare sector for reducing lead time.

Arbulu and Tommelein (2002) applied VSM for reducing the lead time of a supply chain by reducing batch sizes (Açıkkollu, 2008).

Pavnaskar et al. (2003) called for practical VSM applications to be developed to help establish the technique in the scientific sector (Serrano et al., 2006).

Simchi-Levi et al. (2004) are of the opinion that the customers are always concerned with their order status, and sometimes they value the order status more than a reduced lead time. But, McDonald et.al (2002) point out that the VSM creates a common language for production process thus is facilitating more thoughtful decisions to improve the value stream. This will effectively reduce the wastes and improves the productivity. While researchers and practitioners have developed a number of tools to investigate individual firms and supply chains, most of these tools fall short in linking and visualizing the nature of the material and information flow in an individual company (Ramesh et al., 2008).

A. Traylor (2004) stated of his operation at Sunrise Medical: We utilized a simple tool called a Value Stream Map in all of our facilities, in all fabrication and assembly areas. It allows you to look at your current state of operation, and develop your future state of operation, to see where your waste lies, and how you can drive it down. It identifies which activities create value for the customer, and which ones add costs but no value (Michelle Eileen Scullin,2005).

Seth and Gupta (2005) also used VSM in a manufacturing environment. They reduced lead time and cycle time by using kanban and pull systems and reducing batch sizes. Birgün et al. (2006) is an article using VSM in a manufacturing environment. They reduced lead time and cycle time by using kanban and pull systems and reducing batch sizes. Braglia et al. (2006) is another VSM study conducted in a complex manufacturing environment. It used a cellular approach and reduced lead time by using kanban and pull systems. Mehta and Fargher (2005) applied VSM for reducing the lead time of a non-profit organization. They made an investment decision and used a cellular approach. Krings et al. (2006) also used VSM in a non-profit organization for reducing lead time (Açıkkollu, 2008).

Badrinarayana and Sharma (2007) discusses that the interdependent components form the value stream and Value Stream is the set of all specific actions required to bring out a specific product (Ramesh et al., 2008).

Durmuşoğlu and Kulak (2008) used VSM for creating an office cell and reducing lead time. Tatikonda (2008) is another VSM study conducted in an office environment. She reduced lead time by reducing batch sizes and using six sigma and poka-yoke tools of lean (Açıkkollu, 2008).

Although various applications have recently been developed (Jones et al. 2003, Tapping et al. 2002b), originally VSM was mainly focused on the analysis and improvement of disconnected flow lines in manufacturing environments (Rother et al. 1998). This framework is defined and described by Hayes et al. (1979a, 1979b) in a well-known product-process matrix. VSM language (for example, e-VSM and lean-modeller), as have real applications in which VSM maps have been complemented with computer simulations (Yang Hua et al. 2005, Gregory 2003). However, VSM usage is more focussed on generic analysis and improvement rather than the level of precision that can potentially be provided by simulators (Serrano et al., 2006).

2.2 QUALITY FUNCTION DEPLOYMENT (QFD)

Quality function deployment (QFD) was developed in Japan during the 1960s by Akao (1972) as a method for incorporating consumers' demands into product development. Akao and Mazur (2003) defined QFD as a method for defining design qualities that are in keeping with customer expectations and then translating those customer expectations into design targets and critical quality assurance points that can be used throughout the production/service development phase (Gonzalez et al., 2007).

Application fields of QFD (Chan and Wu, 2002): Product development, quality management, analysis of customer needs, product design, product planning and process, master planning, strategic planning, business process planning, quality of services, concurrent engineering, decision making, management, teamwork, scheduling, costing, and others (Gómez et al., 2010).

This method is used in many design fields for various purposes (Chan and Wu, 2002), and it is used at the early investigation and later evaluation stages of a project in order to make more accurate decisions in terms of design quality and client's needs. QFD is capable to lead innovation product designs. An innovative product development process requires an understanding of continuously changing customer wants and needs. Hence, there is a need to study and develop procedures that can help a company or project team gain a profound knowledge of customer requirements (CR) and satisfaction, and then develop products with innovative features (Shen, Tan, and Xie, 2000 ; Xueqin et al.,2007).

In 1966, Yoji Akao had introduced the QFD concept in Japan (Dean 1998). QFD was first put into use at Mitsubishi's Kobe shipyard site in 1972, and later in 1983 it was introduced into the USA (Akao 1990). Since then, it has been used as a product development and quality improvement tool around the world (Akao 1990). Professor Mizuno first used QFD in 1972 to Mitsubishi's Kobe shipyard site to design super tankers (Martins and Aspinwall 2001). According to Cohen (1995) the two pioneer researchers that had developed the QFD were Mizuno and Akao. In the late 1970s, Toyota the automobile manufacturer had adopted QFD and further developed the QFD concept to a detailed process (Cohen, 1995). According to Sullivan (1986) Toyota Auto body had started using QFD in 1977, and as a result, Toyota introduced four new van-type vehicles between 1977 and 1984. Toyota experienced a 20% reduction in the startup cost due to QFD technique adoption in launching its new products from 1977 till 1979 (Chan and Wu 2002) .In 1986, Ford Motor Company and Xerox were the early users of QFD that initiated the use of QFD concept in the USA (Chan and Wu 2002). (Deros et al., 2009).

By employing QFD, manufacturers and service providers are able to translate customer expectations into measurable quality characteristics and create products and services which satisfy those requirements Hauser and Clausing (1988) (Gonzalez et al., 2007).

Within the most important applications of QFD in educational systems we can mention Ermer (1991), Krishnan and Houshmand (1993), González et al (1994), Hillman and Plonka (1995), Mazur (1996), Per et al (1995), Seow and Moody (1996), Gustafsson et al (1996) , Higgins et al (1994), Burgar (1994), Bier and Cornesky

(2001), Hwarng and Teo (2001); Lam and Zhao (1997) and Morelia and Michoacán (2002) .(Gómez et al., 2010).

Several researchers have applied QFD to different service areas (Jeong and Oh, 1998; Trappey et al., 1996; Stuart and Tax, 1996; Cadogan et al., 1999; Pun et al., 2000; Peters, 1988; Gonzalez et al., 2003, 2005). (Gonzalez et al., 2007).

The Cadillac car model 1992, considered one of the great car models that had attracted many customers at that time, this car model has been planned and designed entirely using the QFD technique (Besterfield et al. 1995). (Deros, et al., 2009).

Clayton (1993) used QFD coupled with process analysis to provide cost-effective, high-quality lifelong learning for optometrists-to-be at Aston University (Gonzalez et al., 2007).

Krishnan and Houshmand (1993) Used QFD to address customer expectations in the design of engineering curricula at the University of Cincinnati (Gonzalez et al., 2007).

Chen and Bullington (1993) applied QFD in research strategic planning (Gonzalez et al., 2007).

Wasserman (1993) developed a linear programming model for maximizing customer satisfaction subject to a budget constraint in QFD planning process (Karsak et al., 2002).

Jaraiedi and Ritz (1994) applied QFD to explore ways to improve advising and teaching processes at West Virginia University (Gonzalez et al., 2007). Griffin et al. (1995) have considered that QFD provides a means of communication among product life cycle stages. Benefits which arise from these and other reported QFD applications include lower design and service costs, fewer and earlier design changes, reduced product development time, fewer start-up problems, better company performance, more reliable input for marketing strategies, improved service quality and, above all, increased customer satisfaction (Jae et al., 1998; Franceschini and Rossetto, 1995). (Gonzalez et al., 2007) .

Pitman et al. (1995) applied QFD in evaluating a MBA program at university. The requirements of three groups, i.e. students, employers and academic staff, were taken into account. Their results, though not detailed, revealed the strengths of their present programme as well as areas that required more attention (Singh et al., 2008).

Chang and Ku (1995) used QFD principles to highlight potential improvements to the engineering and technical education in Taiwan (Gonzalez et al., 2007).

Ermer (1995) applied in his study of mechanical engineering department, requirements of customers, students, academic staff and industry-were analyzed separately. In the case of students, their requirements regarding curriculum and teaching processes were compared with measurable specifications of the program. The QFD matrix for staff, however, was quite different, since their own requirements were correlated with the responsibilities of the department management (Singh et al., 2008).

Crowe and Cheng (1996) used QFD in manufacturing strategic planning to link manufacturing strategy and corporate strategy. In addition, they discussed advantages and disadvantages when formulating manufacturing strategy through the QFD process and presented a case study at a powdered metals manufacturer to illustrate the usefulness of the methodology (Delgado et al., 2003).

Motwani et al. (1996) used the three-house approach using American Assembly of Collegiate Schools of Business (AACSB) accreditation requirements as key considerations for designing the MBA program at Grand Valley State University (Gonzalez et al., 2007).

Seow and Moody (1996) used the VOC to improve the curriculum development process at the University of Portsmouth (Gonzalez et al., 2007).

Herzwurm et al. (1997) used QFD to plan the ‘perfect’ QFD software tool (Delgado et al., 2003).

Koksal and Alpay (1998) used QFD in conjunction with AHP to identify general design requirements for the Industrial Engineering program at the Middle East Technical University (Gonzalez et al., 2007).

Lam and Zhao (1998) applied paper addresses the issue of improving quality of teaching with the use of QFD and AHP (Singh et al., 2008).

Owlia and Aspinwall (1998) used QFD principles to identify broad categories of processes relevant to quality characteristics (Gonzalez et al., 2007).

Fiorenzo Franceschini and Marco Terzago (1998) applied QFD to industrial training courses and identified the two major differences between the application of QFD for product development and for education (Singh et al., 2008).

Bouchereau and Rowlands (2000), article explores the integrated use of techniques like fuzzy logic, artificial neural networks, and the Taguchi method with QFD to resolve some of its drawbacks, and proposes a synergy between QFD and these three techniques (Singh et al., 2008).

Hwarng and Teo (2001) demonstrated how an institution in higher education can apply the three-phased, service-based quality function deployment (QFD) methodology to translate the voices of customers (VOC) in stages into operations requirements. The emphasis is at the operational level (Singh et al., 2008).

Aungst, Barton and Wilson (2001) have developed a methodology for mapping from the customer perceptual space to the customer requirements space based on House Zero (Aungst et al., 2002).

Chan and Ming-Lu (2002),It is a review paper highlighting the historical development of QFD, methodological development of technique, applications under the classification of different industries, working of some QFD organizations, and key readings – publications on QFD (Singh et al., 2008).

Sahney et al. (2003), Paper reports a study on educational institutions-industry interaction in Indian perspective using QFD model (Singh et al., 2008).

Hamilton and Selen (2004) conducted a study by using a concept of integrated services in meeting the user needs. Their approach was to find ways on how integrated services can be delivered over the web in a service chain that involved multiple partners (Islam et al., 2007).

Sahney et al. (2004b), an integrated approach of SERVQUAL and QFD model is applied to identify the gaps existing in quality education and customer requirements in today's modern education system (Singh et al., 2008).

Four benefits of QFD for design research have been demonstrated by Dikmen, Talat Birgonul, and Kiziltas (2005), namely, precise collection and identification of client needs/expectations, better planning, enhanced communication and concurrency, and reduced uncertainty (Xueqin et al., 2007).

Thakkar and Deshmukh (2006) ,the paper presents use of quality function deployment (QFD) which prioritizes technical requirements and correlates them with various customers'/students' requirements for the present Indian context. Provides information about the severity of various technical requirements of competitive education (Singh et al., 2008).

QFD has been developed and broadly used in various industries such as automotives, electronics, banking, insurance, healthcare, utilities, food processing, aerospace, software engineering, construction and marketing (Chan and Wu 2003) Many other multinational companies such as IBM, HP, General Motors, AT&T, Digital Equipment, ITT, Baxter Healthcare, Texas Instruments, Miliken Textile, Black and Decker and Philips International have subscribed to QFD advantages (Prasad 1998). (Deros et al.,2009).

Apart from Japan, Akao and Mazur (2003) claimed that QFD is successful in Argentina, Chile, Columbia and many other Latin-American countries. Not only that, the tool has also been widely used in European countries such as Italy, UK, Sweden, Germany, Austria, Spain, France, Denmark and the Netherlands. Other than Europe, Latin-America, USA and Japan, QFD has gained interest in South Africa, Iran, Malaysia, Thailand and Indonesia (Islam et al., 2007).

The first QFD seminar (a 2-day seminar) in Japan was organized in 1983 by Japan Productivity Center, and was followed by many others. Today QFD classes are available through the Japan Standards Association (a 2-day seminar), Central Japan Quality Control Organization (a 3-day seminar), and Union of Japanese Scientists and Engineers (a 4-day seminar) (Akao, 1997).

QFD lectures were also given in Korea from 1978 through 1985 at the Korean Standards Association, but these did not lead to actual applications. In recent years, however, the country is showing heightened interest in QFD. In January of last year, a QFD Research Committee was created in Korea. Taiwan was also introduced to QFD from 1982 through 1986, but actual applications have just begun recently. The Chinese Productivity Center is the leading force in dissemination of QFD in the country. In Brazil, QFD was first introduced in 1989 at ICQC-1989 in Rio de Janeiro (Akao and Tadashi 1989). (Akao,1997).

Today, QFD continues to inspire strong interest around the world, generating ever new applications, 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 (Çelen,2008).

Future TQM will find more importance in how to align company-wide activities to customer focus. It is this author's belief that Voice of Customer should be common bedrock for creating a partnership of such activities. For companies to attain customer satisfaction, it is important that all employees acquire customer focused thinking through the value chain created by the awareness that "the next process is your customer." It is with QFD that companies will be able to accomplish this future challenge. QFD will serve as a tool for creating this alignment, where true partnership can sprout (Akao 1995; Akao, 1997).

CHAPTER 3

AVIATION INDUSTRY AND MRO SECTOR

Maintenance, Repair and Overhaul (MRO) plays a vital role in the aerospace industry. It not only ensures the continued airworthiness of aircraft – and therefore the safety of passengers – but also protects the value of airline assets through regular maintenance.

3.1 AVIATION IN THE BEGINNING

Although there is some controversy over the first powered, sustained and controlled flight of an airplane, Orville and Wilbur Wright are generally accepted as the first men to accomplish this dream. On December 17, 1903, they made four flights on the sand dunes of Kitty Hawk, North Carolina in the aircraft they called The Flyer (ALLSTAR, 2009).

At first, aviation was more entertainment than transportation, but that soon changed. Just as modern jet liners boast dimensions greater than those of the first flight itself, the technological advances in aviation over the ensuing 100 years are equally impressive. And the approach to the maintenance of these complex vehicles has kept pace. Today, aviation is the safest mode of transport in the world. A considerable part of that safety record can be attributed to the effort of mechanics, technicians and engineers, and managers who work in the field of aviation maintenance (Kinnison, 2004).

3.2 A BRIEF HISTORY OF AVIATION

Aviation began as a pastime, a sport, a whimsy. Like so many new and "past-the-edge-of-reason" inventions, flying was considered a fanatic's sport. Through the efforts of people like the Joseph and Jacques Montgofier, Octave Chanute, Otto

Lilienthal, Samuel P. Lamgley, Glenn Curtis, Orville and Wilbur Wright, and many others, we have "earned our wings" .We can fly (Kinnison, 2004) .

Orville and Wilbur Wright who are credited with the first controlled, manned flight. Although, they covered a distance of only 120 feet and got no higher than 10 feet off the ground, their first flight was the result of a concentrated effort to master that which others had only courted. Many experimenters in aviation –some of them with more academic or engineering credentials than the Wrights – had failed to meet the challenges. And some of them, unfortunately, lost their lives in the attempt (Kinnison, 2004).

3.3 LEAN THINKING

The forecasted steady growth of the global MRO market masks significant underlying turbulence as low-cost Asian and Latin American MROs capture increasing market share at the expense of North American MROs. In the coming years, North American MROs will need to reconsider their response to these competitors. Traditional cost cutting will not enable them to bridge the dramatic wage differentials. Instead, they will need to rethink their operations and organizations radically. "Lean" is a proven and comprehensive approach to operational transformation that—by focusing on the customer and eliminating waste—enables companies to simultaneously decrease cycle times, increase labor productivity, and improve quality and reliability (Mercer Management Consulting, 2005).

3.4 WHAT IS 'LEAN'?

The term "lean" was accepted by three researchers from the Massachusetts Institute of Technology, Cambridge, MA, to describe the production system developed, and carefully applied, by Toyota Motor Corporation which made it such a successful manufacturer (MRO Software Inc., 2005; Demiral, 2006).

"Lean" is a business philosophy pioneered by Toyota after World War II. It harnesses a set of standard tools and techniques to design, organize, and manage

operations, support functions, suppliers, and customers. Compared with the traditional system of mass production, Lean meets or exceeds customer requirements while using less human effort, space, capital, and time to make a wider variety of products (Mercer Management Consulting, 2005).

It is ‘lean’ because Japanese business methods used less of everything – human effort, capital investment, facilities, inventories and time – in manufacturing, product development, parts supply and customer relations (Ikovenko and Bradley, 2004; Demiral, 2006) .

Lean is a way of thinking to adapt to change, eliminate waste, and continuously improve. It does not expect us to arrive at perfection. Instead, it stresses an evolutionary process of change and adaptation. It provides a number of tools and techniques to help us maximize the effort of our workforce and to operate as a lean government (State of Maine Department of Health and Human Services, 2007).

Lean Thinking provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want (MRO Software Inc. 2005).

Lean thinking uses a set of standard tools and techniques to design, organize, and manage operations, support functions, suppliers, and customers. Compared with the traditional system of mass production, Lean meets or exceeds customer requirements while using less human effort, space, capital, and time to make a wider variety of products (Mercer Management Consulting, 2005).

Lean Thinking it is very important to define waste. Specifically waste means any human activity which absorbs resources but creates no value. Lean techniques cut costs by eliminating waste—those items and process steps the customer doesn’t value. These reductions paradoxically increase quality as production problems become more visible and root causes more easily identified and remedied in simplified work processes (Mercer Management Consulting, 2005).

The approach increases throughput dramatically by a focus on single-piece continuous flow and a flexible structure of cellular product-family work teams. Since flow starts with the pull of actual customer demand, overproduction is essentially eliminated. Inventory levels are reduced and turns increased through the combination of just-in-time (JIT) and kanban-controlled production. As a result, Lean significantly reduces working capital requirements (Mercer Management Consulting, 2005).

Fixed assets are managed more efficiently through the application of Total Productive Maintenance and revamped accounting systems that seek to measure value in the eyes of the customer. In addition, a by-product of Lean is more available floor space, freeing additional capacity to support a more aggressive sales effort (Mercer Management Consulting, 2005).

Today, companies can realize significant gains by implementing a lean enterprise. The lean alternative is to reorganize the work of functions and departments along the lines of the value stream with work cells and assets that are dedicated to performing certain tasks. By using this approach, unnecessary and non-value adding activities can be removed from the system, leading to a more efficient process (MRO Software Inc, 2005; Demiral, 2006).

3.5 THE PRINCIPLES OF LEAN THINKING

3.5.1 Value

According to Womack and Jones (2003), value is the starting point for lean thinking and it must be determined by the customer, not by the company. Value is a specific product or service (or both), which meets the customer's needs at the right time, at the right quantity, at the right place and for a reasonable price (Açıkkollu, 2008).

In the lean philosophy, "value" is determined by the end customer. It means identifying what the customer is willing to pay for, what creates "value" for him. The whole process of producing and delivering a product should be examined and optimized from the customer's point of view. So once "value" is defined, we can explore the value stream, being all activities – both value-added and non-value added – that are currently

required to bring the product from raw material to end product to the customer (Rother and Shook, 1999).

Next, wasteful steps have to be eliminated and flow can be introduced in the remaining value-added processes. The concept of flow is to make parts ideally one piece at a time from raw materials to finished goods and to move them one by one to the next workstation with no waiting time in between. Pull is the notion of producing at the rate of the demand of the customer. Perfection is achieved when people within the organization realize that the continuous improvement process of eliminating waste and reducing mistakes while offering what the customer actually wants becomes possible (Womack and Jones, 1996; McDonald et al. 2000).

To develop breakthroughs with lean thinking, the first step is learning to see waste. If something does not directly add value, it is waste.

The Seven Wastes of Manufacturing:

- Overproduction
- Inventory
- Extra Processing Steps
- Motion
- Defects
- Waiting
- Transportation

3.5.2 Value Stream

A value stream is a collection of all actions (value added as well as non-value-added) that are required to bring a product (or a group of products that use the same resources) through the main flows, starting with raw material and ending with the customer (Rother and Shook, 1999). These actions consider the flow of both information and materials within the overall supply chain. The ultimate goal of VSM is to identify all types of waste in the value stream and to take steps to try and eliminate these (Rother and Shook, 1999).

The value stream viewpoint means working on the big picture and not individual processes. VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream (McDonald et al., 2002).

3.5.3 Flow

Lean organizations are primarily concerned with making materials flow in the system with high levels of stock turn without allowing the material to idle in queues or stagnate at large stock points. The ability to ensure materials flow within a factory and derive value rather than cost, involves the eliminations all types of Muda. Flow is defined as producing a product from raw material to completion without unnecessary interruption or delay (that is, Muda). The goal is to achieve single-piece flow in each process, ensuring work flows smoothly from one stage to the next, one at a time, increasing flexibility (Sergei Ikovenko , Jim Bradley ,2005).

As a result, we will get reduction in work in progress, part movement, parts handling, quality defects and therefore, the lead time (Sergei Ikovenko, Jim Bradley ,2005).

3.5.4 Pull

This principle derives from Toyota's innovation, the Kanban. The Kanban is a tool that communicates specific production/withdrawal of parts information to the upstream process. The Kanban applies for the lean approach where Flow cannot be used to move materials between departments or processes. At these points it is important to have materials available when required and these key buffers effectively disconnect the internal (or external) customer and supplier operations. The supplier manages then is such a way that withdrawals of products by the customer trigger the manufacture of replenishments. Thus as products are taken to demand, the empty space left by withdrawal provides the "requirement" to replenish (Sergei Ikovenko , Jim Bradley ,2005).

3.5.5 Perfection

Perfection describes the basic attitude that any technical or organizational system always can, and must be continuously improved (Oehmen, 2005).

This last principle highlights the importance of transformation through continuous improvement. Once an improvement opportunity is identified, the process should go through the Plan-Do-Check-Act (PDCA) cycle to strive for perfection (Shiba et al., 2001).

The Lean approach is to apply these principles to identify and eliminate waste. Waste is defined as any non-value added activity (activity the customer is not paying for e.g. material handling, inspection)(Padmaja S.Vanka , 2004).

3.6 KEY TOOLS OF LEAN

3.6.1 5S

5S is a set of methods for creating a clean, tidy and efficient work environment. It is the foundation for other kaizen activities like Accelerated Improvement Workshop (AIW) and Value Stream Mapping (VSM). Thus, 5S is the first step for developing a lean culture in a company (Açıkkollu, 2008).

Creating a clean, organized and efficient workplace makes it possible to see problems easily and distinguish between normal and abnormal work a condition, which is directly related with the production quality (Açıkkollu, 2008).

The common motto for a 5S program is “A place for everything and everything is in its place!” Thus, if a technician, for example, is looking for a tool, then he has to look at only one dedicated place for that tool. Otherwise, he has to look for everywhere in a shop (Açıkkollu, 2008).

The 5S’s are lean concepts derived from the Japanese words: seiri (sort), seiton (set in order), seiso (shine or purity), seiketsu (standardize), and shitsuke (sustain) (Hirano, 1996). Companies adopting the lean production philosophy often implement the 5S process to bring order to the workplace and thereby support lean production (Kimball E.Bullington, 2005).

3.6.1.1 Seiri (Sort)

Seiri (sorting, organization of the workplace, and elimination of unnecessary materials) refers to the practice of sorting through all the tools, materials, etc., in the work area and keeping only essential items. Everything else is stored or discarded. This leads to fewer hazards and less clutter to interfere with productive work (J. Michalska*, D. Szewieczek, 2007).

3.6.1.2 Seiton (Set in order)

Seiton (set in order, place for everything) focuses on the need for the workplace in order. Tools, equipment, and materials must be systematically arranged for the easiest and the most efficient access. There must be a place for everything, and everything must be in its place (J. Michalska*, D. Szewieczek, 2007).

3.6.1.3 Seiso (Shine)

Seiso (shine, cleaning, removing of wastes, dust etc.). A clean and organized workplace makes it possible to see the problems and abnormalities beforehand. This reduces the amount of defects and rework and increases quality and safety. Every table, workbench, shelf, cabinet, machinery or common area must have a responsible for its cleaning and organization. Cleaning the work area must be the last step of every process, which means cleaning must be the responsibility of every employee, not only the cleaning people. Moreover, risks that might break the cleanliness and organization of a workplace must be defined and precautions must be taken (Açıkkollu, 2008).

3.6.1.4 Seiketsu (Standardize)

Seiketsu (standardize, constant place for things, constant rules of organization, storage and keeping cleanness) allows for control and consistency. Basic housekeeping standards apply everywhere in the facility. Everyone knows exactly what his or her responsibilities are Housekeeping duties are part of regular work routines. (J. Michalska*, D. Szewieczek, 2007).

3.6.1.5 Shitsuke (Sustain)

Shitsuke (sustain, automatic realization of above-mentioned rules) this step of moving into the area of “Kaizen” or ongoing improvement. All the previous steps of 5S have been about creating and maintaining a clean and tidy working environment. This phase of 5S is about moving forward not just maintaining the standards you’ve set yourself but building on those and raising the bar (Institute of aerospace excellence, 2003; Demiral ,2006).

3.6.2 Poka – Yoke (Error – Proofing)

Poka-Yoke method was introduced by Shigeo Shingo in 1961, when this was one of engineers Toyota Motor Corporation. This method, in other words, is to prevent defects and errors originating in the mistake (M. Dudek-Burlikowska*, D. Szewieczek, 2009).

In its early days, term poka-yoke was known as baka-yoke, meaning fool proofing. In the operator’s point of view this term wasn’t very attractive, because of term’s dishonorable and offensive connotation. Soon after the name episode in one of the Japanese car manufacturing plants in 1963, the term to describe this methodology was changed to poka-yoke. The term "poka-yoke" stands for mistake-proofing; referring originally devices which serve to prevent (or proof, in Japanese "yoke") the sort of inadvertent mistakes ("poka" in Japanese) that anyone can make (Manivannan, 2006; Shingo,1986 ; Jussi Tapani Sissonen, 2008).

3.6.3 Kaizen

Kaizen (Ky ‘ zen) is a Japanese term that means continuous improvement, taken from words 'Kai', which means continuous and 'zen' which means improvement. Some translate 'Kai' to mean change and 'zen' to mean good, or for the better (KAIZEN, The Key to Understanding Japanese Success, Graphic Products, Inc., 2004).

The benefits of Kaizen are obvious to those who have introduced it. Kaizen leads to improved quality and greater productivity. Where Kaizen is introduced for the first time, management may easily see productivity increase by 30 percent, 50 percent and even 100 percent and more, all without any major capital investments. Kaizen helps

lower the breakeven point. It helps management to become more attentive to customer needs and build a system that takes customer requirements into account (KAIZEN, The Key to Understanding Japanese Success, Graphic Products, Inc., 2004).

3.6.4 Just – in –Time Production (JIT)

JIT is a Japanese management philosophy which has been applied in practice since the early 1970s in many Japanese manufacturing organizations. It was first developed and perfected within the Toyota manufacturing plants by Taiichi Ohno as a means of meeting consumer demands with minimum delays. Taiichi Ohno is frequently referred to as the father of JIT (http://www.productivity.in).

Just-in-time (JIT) is a management philosophy that strives to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. Waste results from any activity that adds cost without adding value, such as moving and storing .JIT (also known as lean production or stockless production) should improve profits and return on investment by reducing inventory levels (increasing the inventory turnover rate), reducing variability, improving product quality, reducing production and delivery lead times, and reducing other costs (such as those associated with machine setup and equipment breakdown). In a JIT system, underutilized (excess) capacity is used instead of buffer inventories to hedge against problems that may arise (Just-In-Time (JIT) Lecture Notes.htm, 2007).

3.6.5 The Kanban System

The Kanban system is the way to manage the Just-in-time production method. In short, the kanban system is an information system to harmoniously control the production quantities in every process. It is a tool to achieve just-in-time production. In this system what kind of units and how many units needed are written on a tag-like card called Kanban. The Kanban is sent to the people of the preceding process from the subsequent process. As a result, many processes in a plant are connected with each other. This connecting of processes in a factory allows for better control of necessary quantities for various products. The Kanban system is supported by the following: (R.Balakrishnan, 2003)

- Smoothing of production
- Reduction of set-up time design of machine layout
- Standardization of jobs
- Improvement activities
- Autonomation

3.6.6 Jidoka (In – Station – Quality)

Jidoka, Quality in Station, Autonomation (making equipment or processes that are “smart” enough to detect an undesired, abnormal state and stop so as not to produce a defective product, normally the word “jidouka” in Japanese means “automation,” but the “dou” of this word refers to “work,” and its kanji character includes the symbol for “person” (nin-ben) which alludes to the capability of a device to “judge” like a person would when inappropriate conditions have occurred and stop its process so as to avoid producing defects) (Fred Harriman, 2005).

3.6.7 Heijunka (Leveled Production)

Level production is called Heijunka. It is defined as leveling of production by both volume and product mix; taking the total volume of orders for a period and leveling them so the same amount and mix are made daily (best case), or during each identified scheduling period. It is the base on which you reduce inventories in a supply chain and build a flow and pull production system. Taiichi Ohno, founder of the Toyota Production System, compares level production to the tortoise and hare story, where the tortoise is slow and steady compared to the hare, which is fast and races ahead but stops on occasion to rest allowing, in the end, the tortoise to win the race (Roy E. East, 2005).

3.6.8 Value Stream Mapping

Value Stream Mapping is a method of recording a product's production path (materials and information) from door to door. It can serve as a starting point for management, engineers, production associates, schedulers, suppliers, and customers to recognize identify waste and its causes. The VSM process involves physically mapping

the current state while focusing on the desired goals, or the future state map, that can serve as the starting point for other Lean improvement strategies (Steve Krar, 2007).

3.6.9 AIW (Accelerated Improvement Workshop)

An accelerated improvement workshop (AIW) is a rigorous, disciplined workshop designed to implement improvements rapidly. The workshop results in the elimination of waste for a defined process, immediate implementation of improvements, assurance that changes are sustained and improved efficiency of the work area. An AIW requires detailed planning and commitments by those who actually perform work where changes are being considered. An AIW typically involves employees who directly perform the work, managers who directly oversee that work, upper-level managers responsible for the operation and, when available, a consultant with experience in lean production. The workshop may last 1 day to 1 week. Benefits of an AIW include immediate improvements, increased communication among team members, and integration of multiple disciplines and empowerment of line-level employees (Matthew R. Hallowell, Anthony Veltri and Stephen Johnson, 2009).

3.6.10 3P (Preparation-Production-Process)

The three Ps stand for Production, Preparation and Process in product engineering and manufacturing process design. In 3P these elements of product development are merged. Design engineers within a manufacturing team employ a lean product development process and the lean process is carried through to product production. The roots of 3P go back to the Toyota production system of the mid-1980s. Toyota’s groundbreaking production system became the quality standard in the automotive industry, and this same standard has been applied to other industries with great success. 3P can be used when there is change in design, a new product launch, or a significant change in the production rate. Benefits from implementing 3P is reduced time to market—get a jump on your competition, reduced product development costs—drive profitability, reduced non-value-added time and materials— an efficient operation helps create a ‘Green’ business (Wisconsin Manufacturing Extension Partnership, 2010).

3.6.11 Fishbone

Dr. Kaoru Ishikawa invented the fishbone diagram who a Japanese quality control statistician. The fishbone diagram is a cause-and-effect diagram that can be used to identify the potential (or actual) cause(s) for a performance problem. Fishbone diagrams provide a structure for a group's discussion around the potential causes of the problem. Fishbone diagrams are often used in needs assessment to assist in illustrating and/or communicating the relationships among several potential (or actual) causes of a performance problem. Likewise, these graphical representations of relationships between needs (i.e., discrepancies between desired and actual results) offer you a pragmatic tool for building a system of performance improvement interventions (for instance, a combination of mentoring, job aids, training, motivation, new expectations) around the often complex relationships found across potential (or actual) causes (WBI Evaluation Group , 2007).

3.7 AIRCRAFT MAINTENANCE, REPAIR AND OVERHAUL (MRO) SECTOR

Airlines and aircraft manufacturers mostly concentrated on their own businesses until the late 1970s. Manufacturers mainly focused on building new models and using the fast evolving technologies to stay competitive in the market. Airlines on the other side, enjoyed these new technologies, but the life-span of the aircraft models was relatively short and after-sales support of Original Equipment Manufacturers (OEM) was poor (Açıkkollu, 2008).

In the 1980s, this business model started to change as a result of some improvements in the aviation technology: (Açıkkollu, 2008)

- Aircrafts, engines and components became more reliable and their service lives increased.
- Thus, airlines spent less money on parts and components. That reduced the cash flow from the airlines to the OEM's.
- Also, the cost of manufacturing and after-sales support increased

- This resulted in higher launch costs for new aircraft models and higher costs for MRO investments.

Maintenance, Repair and Overhaul (MRO) plays a vital role in the aerospace industry. It not only ensures the continued airworthiness of aircraft – and therefore the safety of passengers – but also protects the value of airline assets through regular maintenance.

Simply put, MRO encompasses the maintenance, repair, overhaul and refurbishment of aircraft and aircraft components. By doing so, it ensures aircraft meet the rigorous certification – and safety – standards set by governmental regulatory authorities such as Transport Canada, the US Federal Aviation Administration (FAA), and the European Aviation Safety Agency (EASA) (ExelTech Aerospace, 2006; Demiral, 2006).

The objectives of aviation MRO are : (Kinnison, 2004; Lee et al., 2007)

1. To ensure or restore safety and reliability of the equipment.

2. To obtain the product and process information necessary to optimize maintenance when these inherent safety and reliability levels are not met.

3. To obtain the information necessary for component repair and tooling design for those items to be fully repaired or replaced during the overhaul process.

4. To accomplish these objectives within the required time limits and at a minimum total cost, including the costs of maintenance and the cost of residual failures.

The main stakeholders in the use phase of an aircraft are: the operator of the aircraft, the aircraft manufacturer, part manufacturers, and the company that maintains repairs and overhauls the aircraft. The objective of the aircraft operator is to ensure safe operation at minimal operating costs. Confining service to only those parts of the aircraft that require it, as opposed to servicing all units, increases profitability. Aircraft manufacturers and part manufacturers want products that are safe and easy to maintain. MRO companies strive to minimize maintenance costs and turn-around time to maximize revenue for the owner (Lee et al., 2007).

In the aviation industry, capital equipment and products with long service lives and complex configurations are a challenge. The profitability of the industry is not from the sale of aircraft, but from maintaining them for an anticipated thirty-plus year lifespan (Arbor, 2002; Lee et al., 2007).

For Maintenance, Repair and Overhaul (MRO) of aircrafts, strict regulations define requirements for quality, safety, and documentation. These are the reasons why general process is largely standardized within industry (Lampe et al, 2004; Demiral, 2006).

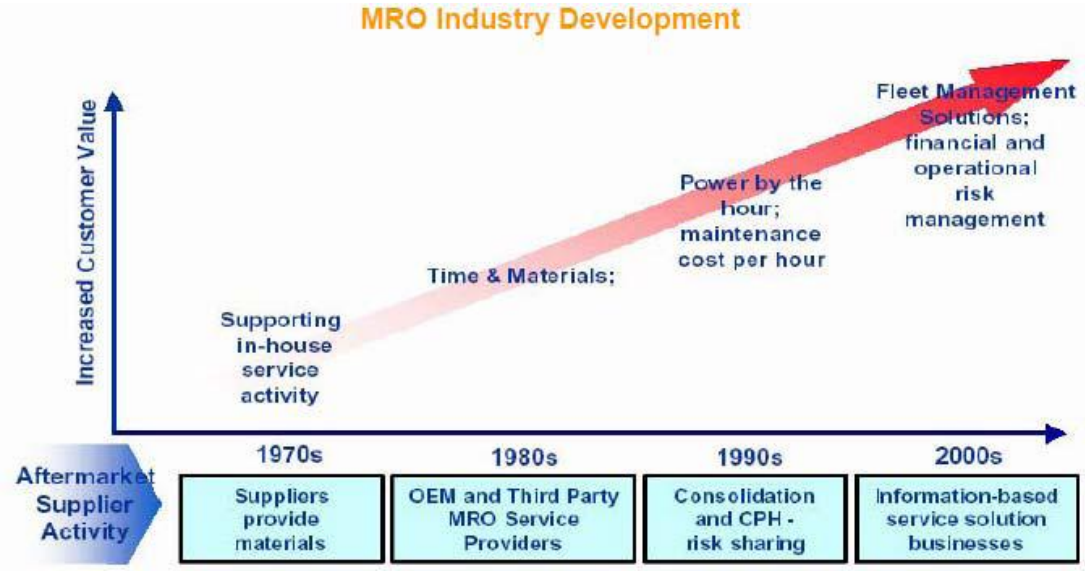


Figure 3.1: MRO Industry Development. (Demiral, 2006)

In the early eighties this traditional picture started to change and change has continued, perhaps the key driver has been the development and application of technology (Demiral, 2006).

MRO operations, multiple things such as parts, mechanics, tools, equipment, paperwork, etc have to come together at each of the repair process to ensure smooth execution. If anyone of these is missing, execution slows down (cycle time goes up) and productivity suffers (throughput comes down) (http://www.realization.com/mro.html).

MRO covers five primary market segments: engine overhaul, heavy checks, line maintenance, component maintenance, and major airframe modifications (Demiral, 2006).

- Engine Overhaul: The periodic removal of engines for inspection and overhaul at dedicated maintenance facilities.

- Heavy Checks: Major structural inspection of the airframes of aircraft, so that potential airworthiness issues can be identified and rectified before they become problems.

- Line Maintenance: Routine maintenance checks performed between flights and during overnight stops.

- Component – Maintenance: The repair and overhaul of major aircraft components, including landing gear, avionics and other electrical and mechanical equipment.

- Major Airframe Modifications; Major modifications required by manufacturer or caused by aging aircraft. These are also performed at dedicated facilities (ExelTech Aerospace ,2006 ; Demiral ,2006).

Aircraft engines are expensive assets for the airlines. As a result, airlines are trying to minimize the inventory of ready engines being held. This puts pressure on engine MRO operators to reduce turnaround times for overhauling the engines. Engine MRO operations are complex. After induction, the engine is disassembled and inspected. Hundreds of parts coming out from the engine are then repaired through a series of shops, both internal and external. All these parts have to come back to the assembly point at the right time. Synchronizing the hundreds of parts to come back to assembly point is a huge challenge. Most often some of these parts are missing at the assembly point. This causes delays, expediting, fire-fighting and loss of throughput (http://www.realization.com/mro.html).

The aircraft maintenance, repair and overhaul (MRO) sector has seen tremendous growth in recent years. From once being a peripheral, although important, cost centre within an airline, the maintenance, modification and aftermarket servicing of commercial aircraft, engines and components has become a truly multi-billion dollar global business (http://www.mromanagement.com/).

Aviation MRO companies, with assets in service for many years, need to focus on persistent product performance. Today, the global commercial aviation fleet includes more than 17,000 active aircraft. The 2005 operating budget for MRO exceeded US$38 billion and an inventory of spare parts is estimated at US$50 billion .Furthermore, analysts expect a growth in operating budgets to nearly US$46 billion in 2010, exceeding US$54 billion by 2015 (UGS, 2005; Lee et al., 2007) .

Clearly, every airline operator seeks cost-effective and reliable MRO vendors for their regular maintenance contracts. An evaluation of maintenance tasks including whether to repair or to replace items is the common task of both the operator and the vendors. Here, detailed product engineering knowledge and procedures involved in any repair are necessary (Lee et al., 2007).

As a consequence, airlines developed strong in-house capabilities to support their own fleets. In those days, senior executives of the airlines generally came from technical operations. Those small MRO structures, developed by the classical airlines, were high cost centers controlled centrally by the airline. They operated in order to support the fleet of that airline (Açıkkollu, 2008).

3.8 AIRCRAFT MAINTENANCE AND REPAIR IN TURKEY

There were two aircraft maintenance hangars at the first airport established between Yesilkoy and Sefakoy, by Mahmut Sevket Pasha in 1912. Turkkusu, which was established at Ankara Güvercinlik Airport, was giving aircraft revision services to National Airlines in 1935. In 1945, maintenance of the DC-3 aircrafts was held at Ankara Etimesgut, Turkish Airforce Aircraft and Engine Factories. In 1950, the Aircraft Factory in wihch different types of engine maintenance and repairs are held since 1940, transformed to Kayseri Aircraft Supply and Maintenance Center. Yesilkoy International Airport finished in 1953, had maintenance hangars within the facility (Turkish Technic internal document).

3.9 INFORMATION ABOUT THE AIRCRAFT MAINTENANCE, REPAIR AND OVERHAUL (MRO) COMPANY

The Aircraft MRO Company; as the provider of maintenance, repair and overhaul operations to primarily to The Aircraft MRO Company' fleet in its existing facilities at Istanbul Atatürk International Airport is also providing maintenance services to various customer airlines both from Turkey and surrounding countries (Turkish Technic internal document).

The years of experience earned within the existing technical facilities, combined with the developed and well-qualified labor force, the strategic location and the increasing market demand has pushed The Aircraft MRO Company to setup a new MRO (Maintenance, Repair & Overhaul) facility. The new facility will be located at the Sabiha Gökçen International Airport, on area reserved for the setup of an international MRO center, which is around 70 km's away from the existing facilities located at Istanbul Atatürk International Airport, Yesilköy. The geostrategic location of the new facility will enable the new maintenance center to reach to European, Asian, North African and Middle Eastern MRO markets, as well as the Turkish market (Turkish Technic internal document, 2010).

Based at Istanbul's Atatürk Airport, The Aircraft MRO Company is the leading aircraft maintenance, repair and overhaul (MRO) services company in the region. Certified through EASA 145, JAA 145, FAA and Turkish DGCA for the performance of maintenance services, The Aircraft MRO Company offers a variety of maintenance services through its diversified shops, including airframe heavy maintenance, engine and APU(Auxiliary Power Unit) overhaul, line maintenance ,base maintenance ,engine maintenance , component maintenance ,authorized Repairs ,etc. (Turkish Technic internal document).

As the only one-stop shop in the region and with its wide range of back shops certified for over 4,000 Boeing and 4,000 Airbus aircraft components, The Aircraft MRO Company offers customers A to Z maintenance services from its base at Istanbul Atatürk Airport (Turkish Technic internal document).

Within its two wide & narrow-body hangars and one VIP & light aircrafts hangar in Istanbul, and one narrow-body hangar in Ankara, The Aircraft MRO

Company provides maintenance services to its business partners, airlines, lessors and financial institutions (Turkish Technic internal document).

With over 77 years of experience and more than 3,000 qualified employees, The Aircraft MRO Company offers you the advantage of using an integrated maintenance, repair and overhaul complex complete with comprehensive services (Turkish Technic internal document).

The Aircraft MRO Company has following certificates: (Turkish Technic internal document)

Turkish DGCA (Directorate General of Civil Aviation)

- FAA (Federal Aviation Administration) Repair Station Certificate
- JAA (Joint Aviation Authorities) JAR-145 Approval Certificate
- EASA-145 (European Aviation Safety Agency) Approval Certificate
- U.S. Department of Transportation DOT D030 Approval for Oxygen Regulator & Recharging Workshop
- K-Q TS-ISO-EN 9001
- ISO 14001 Environmental Management
- ISO 9001 Quality Management
- OHSAS 18001 Health and Safety at Work Management
- AS9100 Aerospace Standard
- AS9110 Aerospace Standard
- AQA International Certificate
- Green Company Certificate

The Aircraft MRO Company has base maintenance capabilities for following aircrafts:

- Airbus 340
- Airbus 330
- Airbus 320 families
- Airbus 319
- Airbus 310
- Airbus 300-600
- Airbus 300 B2/ B4/ C4/ F4
- Boeing 737-400 classics
- Boeing 737-700
- Boeing 737-800 new generations
- British Aerospace RJ 100/ 85/ 70
- Gulfstream Aerospace Corp. G-IV
- Cessna 172

(Turkish Technic internal document)

3.10 AIRCRAFT MAINTENANCE AND REPAIR IN THE AIRCRAFT MRO COMPANY

The first civil aviation company in our country named National Airlines which was established in 1933, is re-organized in 21 May 1955 to carry all air transportation business in Turkey as The Aircraft MRO Company.

In 1957, maintenance and revisions of three DC-3 aircrafts, within the fleet of 28 aircrafts, were made in Yesilkoy Shops. The facility, which also provided motor revision services, became a modern maintenance center using the most recent techniques and started to get orders from foreign aviation companies in a short while.

In 1959, an agreement is signed with Locheed Int., in order to transform maintenance shops into a technical maintenance base for The Aircraft MRO Company, Turkish Air Force and foreign aviation companies. To run the aircraft maintenance and revision facility efficiently, 28 pilots, 9 engineers and 57 technicians were sent to take trainings in United States. Afterwards, 62 technicians were trained in our training facilities.

In the second half of the year 1960 technical maintenance shops reached the capacity to make the maintenance and repairs of aircrafts with pistons and turboprop. For aircrafts; Viscount, P-27 and DC-3; all kinds of maintenance on the aircrafts and revisions over 50% of their components were held.

By end of the year 1963, our shops reached the international civil aviation standards in both equipment and technical resources, in order to give any maintenance, repair and revision services for aircraft bodies, motors and accessories.

In the year 1968, the Technical Management's works have reached its top level; 15 aircrafts were given maintenance or revision services and near 70 components of DC-9 aircrafts were overhauled.

In 8 March 1973 FAA certificate (certificate nr: 820-1F) is taken to prove our facilities are at international standards; in order to serve Turkish civil aviation, by our shops which are equipped with special tools bought with new investments and our experienced personnel with civil aviation licenses. 95% of the constructions of engine test building, hangar annex and shops, base maintenance shops and power plant; which all make up the new maintenance base of The Aircraft MRO Company; are completed at the end of 1975.

Joint Aviation Association (JAA), found our Technical Maintenance and Flight Administration systems compatible with its regulations and rewarded The Aircraft

MRO Company with Joint Aviation Regulations (JAR) certificate in 1996. With this certificate, our technical maintenance facility became authorized by both FAA and JAA for giving maintenance service in international standards.

In June 1999, Second Maintenance Base Hangar; which has 13.000 m2 of closed area and 67.200 m2 annex section with the capability of giving maintenance and repair services to all aircrafts in The Aircraft MRO Company fleet within international standards and all recent technologies; has utilized.

With the utilization of the Second Maintenance Base, continuously grooving The Aircraft MRO Company fleet's maintenance and repair needs are fulfilled, while customer requests are compensated more compared to the previous years. To raise the Company's share in the market and to fulfill the increasing domestic and foreign customer requests, Aviation Maintenance, Repair and Modification Center (HABOM) project is developed (Turkish Technic internal document).

3.11 LEAN MAINTENANCE AT THE AIRCRAFT MRO COMPANY

With the birth of Lean Production System (Lean Manufacturing System), at the enterprises (organizations that producing goods and service) has been targeted to minimize the effects of cost factors on profitability and eliminate unnecessary processes of production.

The event, thus enhancing the competitiveness has been indexed continuously improving of the current system. In this sense, the implementation of Lean Maintenance System; determining unnecessary activity steps at the maintenance processes to increase efficiency of the process has been simplified and this step has been called sterilization. Lean principles at The Aircraft MRO Company has been applied in order to eliminate wasted space, movement and time so that the technicians can concentrate their full efforts on the tasks directly related to servicing the aircraft.

Using Lean techniques at The Aircraft MRO Company has cut the costs to eliminate waste. The documented results of adopting Lean principles include shorter

turn-around times, efficiency in operational costs, improved management effectiveness, improved workplace organization and continuous focus on real-world customer needs.

Working lean workshops at The Aircraft MRO Company, 5S controls, showing standardization efforts, decreasing of the offered the costs of the services, improving the quality of work and therefore offers a contribution to the point of improving the efficiency ratios.

Intended level of productivity, especially to reach levels of the industry's leading MRO companies and even ahead to take a way towards the goal is to become a leading company in the sector.

Lean Maintenance System Tools at the Aircraft MRO Company;

- 5S Controls
- VSM (Value Stream Mapping)
- AIW (Accelerated Improvement Workshop)
- 3P (Preparation-Production-Process)
- Fishbone (Cause-Effect Diagram)

Applications are available.

CHAPTER 4

IMPLEMENTATIONS

In this implementation were Value Stream Mapping (VSM) and Quality Function Deployment (QFD) concepts applied in a Maintenance, Repair and Overhaul (MRO) Company, which operates in aviation sector.

4.1 VALUE STREAM MAPPING METHOD

The critical starting point for lean thinking is value. Value is the information or product that the customer is willing to pay for and can only be defined by the ultimate customer (Womack & Jones, 1996). The value is defined by the customer and created by the producer. From the customer's standpoint, this is why the producer exists (Womack & Jones, 1996). Many producers only want to make what they are already making and the customers will often settle for what they are offered. Producers do not see what the customer or consumer really wants. When the customer no longer accepts what they are given, producers tend to use techniques such as lowering pricing or offering a variation of the same in order to entice buyers to purchase their product (Carr, 2005).

A value stream is all the actions (value-added and non-value added) required to take a product from raw material to the customer, the design flow from concept to completion. Taking a value stream view means looking at the whole picture, not just individual processes, and improving the whole, not just individual parts. Value Stream Mapping is a pencil and paper tool that helps to see and understand the flow of material and information as a product makes its way through the value stream. The meaning is simple: Follow a product's production path from customer to supplier, and draw a visual picture of every process in the material and information flow. Within the production flow, the movement of material through the factory is the flow that usually comes to mind. But the information flow must also be considered since it tells each process what to make or do next; both flows must be mapped (Krar, 2007).

Value Stream Mapping (VSM) is the macro tool of lean management. It provides a broad view of the information and material flow of a company's core processes, which makes it possible to see the bottlenecks and wastes, focus on the global maximum for these main processes and not on the local maximums (Açıkkollu, 2008).

Value stream mapping is a visual representation of the material and information flow of a particular product family (Tapping, Luyster & Shuker, 2002). Value stream mapping consists of the creation of a current state map and a future state map. The current state map charts the present flow of information and material as a product goes through the manufacturing process. Its purpose is to help understand how a product currently flows. The future state map is a chart that suggests how to create a lean flow (Carr, 2005).

At a more tactical level the value stream mapping can be used to identify where waste lies in a particular process and how it can be achieved more effectively. There is extensive literature on using process analysis in this way as part of lean construction (Alarcon 1997). An important difference between construction and manufacturing is that in manufacturing the production processes exist per se and can be walked on the floor. In the traditional construction process these operating processes are defined as they are needed and until construction teams have more continuity within one product field they cannot be recognized as generic processes (Garnett et al., 1998).

In a VSM workshop, team finds out problems and wastes inside the value stream, and then produces solutions (kaizen items) to improve current situation. Most of these kaizen items are the scope of Accelerated Improvement Workshops (AIW), Huls described 12 steps of a VSM workshop (2005): (Açıkkollu , 2008)

1. Validate & Prepare
2. Train the team
3. Finalize scope & goals
4. Develop process outline
5. Conduct interviews
6. Map the current state
7. Define the value

8. Map the future state
9. Assign action items
10. Celebrate & close
11. Execute actions
12. Follow-up meetings

The value stream identifies all those steps required to make a product. The key technique behind the value stream is that of process mapping. However, it is process mapping for a very specific reason; that of understanding how value is built in to the building product from the point of view of the client. At a strategic level it offers a perspective on defining what is to be done. By taking this top down approach, the idea of identifying value streams such as the structure and the building envelope and considering how these systems will be designed, supplied and constructed, offers a different way of organizing for construction. It gives purpose to the concept of technology clusters, which Gray (1996) postulated (Garnett et al., 1998).

The real goal of VSM is to produce the future-state map, which essentially plots an optimized production system. This is ultimately realized when lean is implemented on the actual factory floor (Rosentrater et.al, 2006).

Generally a VSM tool contains both a current state map and, one or more future state maps that represent progressive improvements to the current state map. Before drawing a current state map, a particular product or product family must be chosen as the target for improvement. The current state map is the beginning point of the enterprise transformation: it represents the baseline condition of how the company organizes and progresses work. The map itself solves no problems; rather, its purpose is to point to problems in the company's work streams (Keyte et.al, 2004; Arı , 2010).

To achieve the future state, however, the current state must first be understood. A system's current state can only be defined after thoroughly examining the production floor, and analyzing the complete path a product takes through the plant, not necessarily according to the physical plant layout, but by major processing steps, wherever material or information flows occur. For each process, it is important to note the Cycle Time (CT), and Changeover (i.e., Setup) Time required. Other pertinent information includes production (batch) size, number of operator's required, effective working time, and

scrap rate. Product flows must be defined as either push or pull, depending on the production process. After all processes and material flows are delineated, it is imperative that all information flows, both electronic as well as manual, be placed on the map as well, especially scheduling information. Finally, a timeline must be added, so that the production process can be analyzed quantitatively (Rosentrater et.al, 2006).

The current state map is essentially a snapshot capturing how things are currently being done. This is accomplished by following the selected product from beginning to end, observing every process. The second aspect of the current state map is the information flow that shows how each process knows what, and how much, to make. The information flow is drawn on the upper portion of the map, left to right. Travel time is the time taken for the information to reach from one process step to another, and is shown on the information arrows. Every process box there will display both value-added time and non-value-added time for the given step. The value-added time represents the sum of the processing times for each process, while non-value-added time is the time that is taken for waiting and backlogs. After the completion of the map a timeline is drawn below, showing both the value added time and non-value added time for the complete process (Abdulmalek et.al, 2006; Abdullah, 2003; Arı, 2010).

The lead time for each process should be denoted on the top position of the timeline, while the processing time should be provided on the bottom position. This allows a total Production Lead Time, as well as a total Processing Time, to be calculated for the entire production line (Rosentrater et.al, 2006).

VSM has been used in aircraft manufacturing. Current and future state maps were developed with the objective of reducing lead time, according to customer requirements (Arı, 2010).

After the current state has been mapped, the production process must be examined and analyzed so that it can be improved, and thus the future state map can be drawn. One of the primary reasons to examine the current state map is to quantify overproduction of items and wasted time, where inventory sits idle, waiting to be used by the next process. The map should be examined for areas where the concepts of lean manufacturing can be utilized to reduce or eliminate wasted time, and by so doing

minimize lead times, and thus streamline each process. Eliminating processing steps, adjusting specific processes, incorporating continuous flow or pull systems, and leveling production are some of the techniques that can be used. More information regarding lean techniques and strategies can be found in the literature, including Dailey (2003), Liker (2003), and Womack and Jones (2003). (Rosentrater et.al, 2006).

VSM is to create a future state map, which is a picture of how the system can look after the wastes have been removed. The purpose of value stream mapping is to highlight target areas for improvement. The future state map is an implementation plan that details which Lean tools are needed to eliminate waste in the value stream. Creating a future state map is done by answering a set of questions on issues related to efficiency, and on technical implementation related to the use of Lean tools. This map then becomes the basis for making the necessary changes to the system (Abdulmalek et.al, 2006; Abdullah, 2003). A similar method is used for drawing the future state map as with the current state map (Arı , 2010).

The future state map uses lean manufacturing techniques to reduce or eliminate wastes and minimize non-value added activities. The future state map is used to help make decisions and plan future process improvement projects (Carr, 2005).

Value stream mapping has many benefits. Mapping will help visualize the entire production of a product at a plant level, not just single process level. It is important to be able to understand the entire flow of a product at a plant level to best understand what to fix. A particular process may appear to be a problem, but when looking at the entire manufacturing process it may not be a problem at all. Value stream map will help identify the source of the real problems. Value stream maps will help show wastes and more importantly help identify the sources of waste (Carr, 2005).

Involving people early in things such as continuous improvement (Kaizen) programs and value stream mapping will earn their cooperation and give the process a better chance of being a success. Organizations that involve people in the overall planning process will come closer to reaching world-class status than those that do not. People, and their focus on eliminating waste, are very important to successfully implementing and maintaining a Lean system. Value Stream Management only works as well as management's skills in promoting people's well being (Krar, 2007).

4.2 THE VALUE STREAM MAPPING DEFINITION

The Value Stream Map is a valuable planning tool and can be used for a developing and implementing lean improvement projects. The process of creating a Value Stream Map helps to train the team on lean techniques and to reveal opportunities to reduce waste. A completed Value Stream Map can be used as a visual communications tool to explain how lean techniques can reduce waste in the value stream. Value Stream Maps become the first step towards achieving the following:

- Shortened lead times
- Fast identification of waste in the value stream
- Identification of process improvement projects to eliminate the waste and achieve continuous flow (Garcia,2005).

Value Stream Mapping (VSM) is a visual tool that integrates material flow and information flow into a critical path chart to understand the relationships and importance of all Value Added and Non-value Added actions. This methodology enables the team to prioritize projects for a systematic Lean approach (Ramesh et.al, 2008).

The value stream map development process consists of the following two steps: (Garcia, 2005)

- Development of the Current State
- Development of the Future State

4.2.1 Current State Value Stream Mapping

The current state map is a fancy way of saying ‘what happens now’ or the ‘as-is’ process. The current state map should show all the process steps and sufficient detail on how each step is completed and what happens to the items being processed. This will enable us to spot the causes of problems and thus the means to improving the flow, efficiency, reliability and flexibility of the process (Ad Esse Consulting Ltd., 2007).

Developing a current state map involves four stages, These are: "(1) gather details about the customer's requirements; (2) detail the physical flow with all processes, data boxes and inventory triangles; (3) map the supply of materials; and (4) map the information flows and determine push and pull system" (Brunt, 2000; Lee ,2001).

Before mapping, Seth and Gupta (2005) encourage the establishment of team work to understand the principles of lean manufacturing. The second stage is to determine the current state from the customer point of view and from the organization a point of view (Womack, 2006). For instance, the customer would like to have cheaper product or the company wants to increase its utilities (Caballero, 2006).

To draw a current state map of the existing process, current state map was prepared with a pencil and paper using icons for various processes to visualize the flow of material and information (Grewal, 2008).

To draw the Current State Map;

• Identification and drawing the product flow from the raw-material entry point of the manufacturing division (MFD) to the finished goods exit point of the MFD.

• Calculating the number of Work-in-process (WIP) for each component at each work cell.

• Calculating the cycle time set up time and utilization percentage of each process

• Plotting the Current State Value Stream Map based on the data collected (Ramesh et.al, 2008).

All the data for current state map is collected according to the approach recommended by Rother and Shook (1999). The data boxes are prepared to capture the changeover time, available time and cycle time. The production lead time and value-added time were noted on the current state map. It provides the snapshot in time. Inventory storage points in between the stages are shown in triangles. The timeline at

the bottom of the current state map has two components. The first component is the production lead time and second component is value-added time or processing time. Value-added time is calculated by adding the processing time for each process in the value stream. The cycle time for each is the average cycle time, which is determined by using actual data from the company (Grewal, 2008).

VSM is to develop a map that includes a number of symbols that helps to recognize workstation, cycle times, inventories, and number of workers (Seth and Gupta, 2005). These symbols represent a part of the big map. There are 3 types of symbols: Material flow, information flow and general symbols (Caballero, 2006).

Table 4.1: Material Flow Symbols (Adapted, in part, from Rother and Shook, 2003)

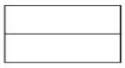
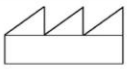
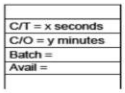
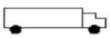
Symbol	Title	Definition
	Dedicated Process	This symbol denotes a process, machine, or department through which materials flows.
	Shared Process	This symbol denotes a process, machine, or department that multiple value stream products share.
	Customer or Supplier	This symbol denotes either a customer of the product, or a raw material supplier.
	Data Box	This symbol is used to summarize essential information for a process, machine, or department, especially demand, batch sizes, and frequency.
	Inventory	This symbol denotes raw material levels, the inventory build-up between process steps, and finished product levels.
	External Shipment (Receiving or Shipping)	This symbol denotes shipment of incoming raw materials, and shipment of finished goods out of the plant.
	Push Arrow	This symbol denotes movement of material that is produced and then sent (pushed) to the next process step.
	Shipment (Receiving or Shipping)	This symbol denotes movement of incoming raw materials, and movement of finished goods out of the plant.
	FIFO Lane	This symbol denotes a First-In-First-Out inventory that limits flow between processes.
	Supermarket	This symbol denotes an inventory of parts used to reduce overall inventory levels that are essential for downstream processing.
	Material Pull	This symbol denotes the withdrawal (pull) of materials from a supermarket inventory for downstream processing.

Table 4.2: Information Flow Symbols (Adapted, in part, from Rother and Shook, 2003)

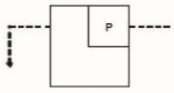
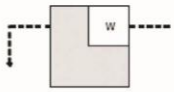
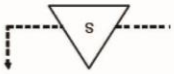
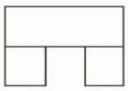
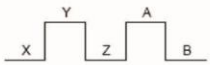
Symbol	Title	Definition
	Manual Information	This symbol denotes manual flow of information (hardcopies, memos, notes).
	Electronic Information	This symbol denotes electronic flow of information (email, fax, phone, computerized data transmission).
	Production Kanban	This symbol denotes the production of a specific number of parts.
	Withdrawal Kanban	This symbol denotes the transfer of parts out of a supermarket inventory to a specific process.
	Signal Kanban	This symbol denotes a material pull, but when inventory levels have dropped to a minimum level.
	Production Control Information	This symbol denotes production scheduling information.
	Load Leveling	This symbol denotes the adjusting of kanbans to level production of parts over time.
	Sequenced Pull	This symbol denotes the production of a specific number of parts without using a supermarket inventory.
	Go See Scheduling	This symbol denotes scheduling production based on visually inspecting inventory levels.
	Verbal Information	This symbol denotes the flow of verbal information.
	MRP/ERP	This symbol denotes the use of central production scheduling, such as MRP or ERP.

Table 4.3: General Symbols (Adapted, in part, from Rother and Shook, 2003)

Symbol	Title	Definition
	Kaizen Burst	This symbol denotes a potential process change that can be used to improve the Current State.
	Safety Stock	This symbol an inventory that is used in case of downtime to protect the production system from disruption.
	Human Operator	This symbol denotes a human operator at a specific workstation. The number of operators should be noted.
	Human Operator	This symbol denotes a human operator at a specific workstation. The number of operators should be noted.
	Workcell	This symbol denotes a workcell where several processes are integrated.
	Timeline	This symbol denotes value-added times (lower) and non-value-added times (upper) for each stage in the production process.

The symbols of material flow represent the machines, suppliers, customer, inventories, and trucks shipment; and the collected data is kept on a process box. The lines are used to connect the information flow that includes manual, electronic, kanbans and heijunka leveling. They usually have description boxes to explain the information flow. Womack (2006) mentions that there are 2 types of information flow that have to be identified, the first one that constitutes the product and the other one that regulate the flow of the product (Caballero, 2006).

In addition to flow, the Current State Value Stream Map shows key production processes and the important data for each process box. Some of the more important data that is recorded is as follows:

- Cycle time
- Changeover time
- Number of people

• Available working time

• Quality data such as reject percentage or scrap rate

• Equipment reliability data such as percentage of uptime

Raw material and finished goods inventory are shown as well as work in process between the various processes in the value stream (Garcia, 2005).

To identify the lean metrics from the process such as inventories, days of inventories, defects, work in process (WIP), cycle time, value added, non valued added, availability, lead time, uptime, change overtime, and so on (Tapping, 2002). This information is allocated in a process box. Lean metrics can help to find the possible lean assessment and to implement this in the future stage. Some of these lean tools are 5s, teamwork, kaizen events, total productive maintenance (TPM), standardize process, visual control, six sigma, Total quality system (TQM) and so on (Caballero, 2006).

The analysis of the map consists of identifying the various ways in which the Lean principles can be applied. These are likely to include:

• Moving from a push to a pull process,

• Reducing batching,

• Balancing the capacity of the different stages of the process,

• Eliminating non value-adding steps,

• Moving decision points to earlier in the process,

• Simplifying individual steps,

• Reducing the cycle times or changeover times of individual steps,

• Improving the flow of information between steps.

As well as other specific improvement activities (Ad Esse Consulting Ltd.,2007).

Current state map provides a picture of existing positions and guide about the gap areas. It helps to visualize how things would work when some improvements/changes are incorporated. The gap area in the existing state results in a road map for improvement (Grewal, 2008).

The aim of the map according to Womack (2006) is to identify the value (creates the value from the customer point of view), capability (good quality in the product is achieved), availability (the percentages that the equipments are available to work), adequacy (the capacity to respond to customers' orders) and flexibility (facility to change the process) (Caballero, 2006).

4.2.2 Future State Value Stream Mapping

Once the current state map is complete, the team can set its sights on creating the future state map. Make sure the team members have some basic training on lean principles to develop a realistic future state map (Manos, 2006).

Rother and Shook (1999) has discussed that, mapping helps to see the sources of waste in the value stream. The reward of VSM is the elimination of large amounts of wastes in the organization. The extended value stream mapping includes suppliers and customers in their decision to suggesting Future State Value Stream Map (Ramesh et.al, 2008).

The Future State Value Stream Map shows how the shop floor will operate after lean improvements have been implemented. The Current State Value Stream Map serves as the starting point for developing the Future State. The goal in developing the Future State Map is to make the flow continuous and to eliminate as much waste as possible (Garcia, 2005).

The starting point for creation of the future state map is understanding and calculation of TAKT time. TAKT time is used to synchronies the pace of production with pace of sales. 'TAKT time' may be defined as the rate at which customers are buying products from production line, that is, the unit production rate must be met to match the customer requirements. TAKT time is calculated by dividing available working time per shift (in sec) with the customer demand rate per shift (Grewal, 2008). Takt time= available working time / customer demand

Lead time is shortened as much as possible by implementing lean techniques. The flow in the Future State Map is built around the takt time, or how frequently a unit must be completed to meet customer demand (Garcia, 2005).

Next the mapping team draws the Future State Map that improves the flow and reduces waste in the value stream. This future state must meet the customer requirements and includes the necessary process improvements to achieve the Value Stream vision. The mapping team revisits the initial business objectives and reviews the current state map to capture their initial ideas for changes. Key to improving the flow of the value stream is the elimination of the root causes of the wastes identified in the Current State. One note: there is no single correct Future State. The mapping team should design a future state that directly applies to the business goals of the enterprise and that the organization can implement in a reasonable time (Thorsen, 2005).

4.3 USE OF VALUE STREAM MAPS FOR IMPLEMENTATION AND PLANNING

When the Future State Value Stream Map is completed, an implementation plan must be developed to convert the Current State into the Future State. The Future State Map can be broken into different loops for ease of implementation. The Current State Map can also be used to show the key process improvements that must be completed to achieve continuous flow in the Future State. Highlighting the process improvements on the Current State Map makes it easier to explain to management and how the changes are related to current operations. The plan should be established to complete the majority of the projects within three to six months (Garcia, 2005).

For the mapping team is to develop a detailed Implementation Plan that describes the necessary improvements to realize the Future State. The mapping effort is simply a tool; implementing the plan is the key to success. A strong Implementation Plan must be achievable, yet aggressive, and anticipate questions and concerns. It must also include a communication plan with associated documentation and established reviews to confirm the results. This detailed plan is critical to the leadership team’s efforts to track, manage, and react to the progress of the implementation activities. By tying the Value Stream design to the organization’s business objectives, the

accompanying lean transformation will have a better chance of taking hold and becoming a new way of life (Thorsen, 2005).

4.4 TECHNIQUES AND TOOLS USED TO DEVELOP VALUE STREAM MAPS

Value Stream Maps have traditionally been hand-drawn and developed by a cross-functional team that has representatives from various company functions that are familiar with the product family being mapped. The advantage of this approach is that the team members become trained in implementing lean techniques and take ownership of the improvements required to achieve the Future State. Another method is to have a small team working with an outside consultant who draws the Current State Value Stream Map using data and input from the team. This team can consist of management personnel or a combination of technical and production personnel. This approach works well when the company has limited lean experience and wants to get a "big picture' concept of what lean techniques can be implemented along with the potential benefits. The Map is then presented to the team for critique, and the Future State Map is developed interactively with the team. The use of Microsoft PowerPoint and Visio has been found to facilitate the Value Stream Map development process (Garcia, 2005).

4.5 AN APPLICATION OF VSM IN CALIBRATION FACTORY

VSM is about building value for the customer by eliminating waste and non-value added work. The purpose of the study is to suggest ways to reduce lead-times and non-value added time minimized. In this VSM application, the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices will be analyzed. This workshop serves to a purpose, which is to yield at least 10% a year with company's efficiency techniques and to maintain its sustainability. In the current situation if the testing and measuring devices are not under the capacity, they are sent to domestic and abroad for calibration. In the process, there is a great amount of time wasting.

The time for the shipment of devices is too long, thus we have built up some constraints. In this VSM the primary key driver is time. On the other hand, the weakest requirement is the cost. Here, performance and quality have not been taken into consideration. In this VSM scope is the testing and measuring device. The expected deliverables in this application have been determined as JIT (delivering to the customer on time) and the mapping of the process. The boundary is the duration from arriving on the factory to the delivering to the customer (equipment rooms). Customer standards (CTQ) have been determined as JIT (delivering on time) delivering. In this application, budgets do not exist. In revision and progress periods (Tool gates, Milestones Periods), however, the kaizen items are controlled by every director and The Process Improvement Manager is notified about the closing kaizen items.

Our customers in this application are the equipment rooms or factories in the company. In this VSM we accept U° as the number of people, R\ T as the runtime, S\T as the setup time, C\T (Cycle time) as the sum of run time and setup time, Q\T as the waiting time, and L\T as the sum of cycle and waiting times, the total process. In this application one day is accepted as 6 hours. One day, one hour and one minute have been indicated as 1g 1 °1' . Normal device delivery is 800 in number. Lead pencil has been used in the value stream map.

This workshop has been performed with a team with 10 people from 8 different units. These units are the Domestic Purchase Department, Calibration Factory, Aircraft Maintenance Department, Delivery Receipt Storage, Customs, Department of Finance, External Purchase Department and the Supplier. These units have been indicated with colorful post-its. The light pink post-it shows Domestic Purchase Department, Pistachio Green post-it shows Calibration Factory, yellow post-it shows the Aircraft Maintenance Department, Grey post-it shows the Delivery Receipt Storage, dark blue post-it shows the Customs, dark yellow post-it shows the Department of Finance, light green post-it shows the External Purchase Department, white post-it shows the Supplier and dark pink post-it shows the Kaizen Items. For this workshop we used Microsoft Visio to create current state and future state VSMs. From the current state map we have tried creating a future state map of the process first on paper and then using Microsoft Visio. The maps include many icons such as production-flow icons, material flow icons, information-flow icons, and lean manufacturing icons. When improvements made to a

system generally, two types of VSMs have been created. The current state VSM has been created to take a “static picture” of the flow through the system as it currently exists. Future State Map improves the flow and reduces waste in the value stream.

Duties of these units are briefly;

DOMESTIC PURCHASE DEPARTMENT: The unit in which material purchase, material repair and auction operations are performed.

CALIBRATION FACTORY: The unit in which The Aircraft MRO Company maintenance organizations and the calibration, repair and maintenance services given to the testing and measuring devices of the customers performed.

AIRCRAFT MAINTENANCE DEPARTMENT: The unit in which any kind of maintenance, repair, modification and design of the air platforms and components are performed.

DELIVERY RECEIPT STORAGE: The unit in which the materials ordered by the Domestic Purchase Department and the External Purchase Department are received and put physically on the storage by the storage officers, and in which any kind of follow-up of these materials are done in the TAMES system.

CUSTOMS: The unit in which the entries (Import) of the materials imported from abroad (aircraft and aircraft parts, materials and devices of ground equipment ,Flight Operation, Ground Operation, Flight Training, Advertisement, Cockpit, Electronic Data Processing, material and devices, technical documents, IATA documents etc.) and the customs clearance operations (Export) of materials sent abroad are performed and in which the payments of customs, funds, imposts, entrance fees, value-added-taxes and storage are made.

DEPARTMENT OF FINANCE: It is the unit which maximizes the activity in management of investment, fund and budget by offering planning between customer and supplier, budgeting and monitoring, and by presenting a reporting that management will need in the frame of finance-effective-profit with systematical record and reporting.

EXTERNAL PURCHASE DEPARTMENT: The unit that provides materials which are asked by planning and user units and will be obtained from abroad, within current law, legal decisions, regulations and memorandum; and that organizes necessary fees, conducts a market research upon materials need from abroad by the company, keeps necessary records within this target and gives decision upon obtaining materials suitable in quality and economically.

4.5.1 Current State Map (CSM)

For Current State Map, first admissions should be done. Admission process of the device starts with opening the TAMES screen and introducing the device. In the process which starts with admission of the device, it is checked whether there is RAR or not, first in domestic, then abroad. RAR (Repair Action Report), means tracking the device through system and the document which is produced for devices sent abroad in TAMES.

The process abroad is divided into two according to whether there is RAR or not. If there is RAR in their calibration in calibrated or need to be calibrated, devices which are going to be sent abroad, an Inclusion is formed; it is recorded in the database and by preparing the RARs, External Purchase Department prepares a Repair Order (RO) after the automatic message, sent from the system. Through the RO chief of repairs it is sent to shipping.

In this situation, shipment waits in the device calibration factory. It requires the device from shipping calibration factory and does the packaging of the device, and prints the shipping order documents when the device is given to them. Later, shipping sends the documents to the customs. After this, the custom process starts.

Shipping order comes to customs from the shipping. Document arrives there before 09.00 am, and is sent by 11.00 am. In this period, document is recorded to books and documented to files. Recording, giving the record number and filing period processes are done. The document goes in process in that same day. Document is sent to the cargo and its declaration is prepared. If the document arrives before 11.00 am, the shipping order and repair order are prepared. After the preparation of the documents the list is sent to the shipping.

Shipping delivers the materials to Warehouse i.e. Cargo. Its declaration is written and the custom processes are done in Cargo. It is loaded to the aircraft. If the document arrives after 11.00 am, the document waits until the next day. Documents that arrive in the morning are sent in that same day.

When the aircraft comes and after the delivery order comes, it is sent to the custom office. It is given to the related desks for recording. (Taking the job and assigning the related person) Information comes from the aircraft and the delivery order of the material is taken. It is delivered to the Repair Management. There is a waiting period in the process of checking the in and out documents. The preparation goes underway in The External Purchase Department processes. Documents come from the Repair Management. The distribution of the documents, printing the tariff, writing the declaration, RUSF payment (tax), registration of the declaration, payments of the taxes, and exit from the warehouse, getting materials are done and material is sent to delivery. This is valid for documents that come fully prepared only.

After the custom process it is delivered to cargo. When device arrives to company's customs again after the supplier finishes the process and gets the device, the delivery process starts. In the meantime the documents arrive to the Repair Management. The required documents are completed, invoiced and the custom processes ended.

Now the delivery process starts. Sending one person from delivery, the materials are taken. Except AOG (Immediate Material) (Aircraft on Ground) all materials are ordered according to their urgency. After the delivery, materials enter the warehouse. After the delivery process ends, automatic message is sent to the Calibration Factory. The Calibration Factory takes the device from delivery, certifies it and delivers the device to the customer.

If there is no RAR in their calibration in calibrated or need to be calibrated devices which are going to be sent abroad, RAR is produced, an Inclusion is formed and recorded in the database. As soon as the RARs are done by the factory, a message arrives to External Purchase Department. If the repair station and the vendor are known, a repair order is issued. If it is not known, an address confirmation is requested from the company. This period is related to the company's answer. It may take for a week .

After the address is acquired, the company is introduced to TAMES. After 3 or 5 minutes, a Repair Order is prepared. RMA (Repair Material Authorization) number is taken from some suppliers and if the repair station is not known, in other words if there is no history of doing business together, R\O is issued and later the Repair Order (RO) is delivered to secretary and the secretary sends the shipping request form to the shipping.

It is checked whether there is RAR or not on domestic in the process which starts with the admission of the device. After the document of requirement approved by the manager comes to the External Purchase Department it is checked with eyes no matter there is RAR or not. Then, the purchase employees are assigned. A document which arrives in the morning has a waiting period until 10.00 a.m on the next day. After the assignment, device leaves by cargo or one of our vehicles. Confirmation comes from the chief. If the device is for outside of Istanbul, packaging is done. If it is worth for transporting, in other words, if it is an easy delivery, company delivers the material with one of its employee by a vehicle of the company, and does the delivery. If the material doesn't worth for transporting, in other words, if the material is not an easy delivery, then preparations are done for delivery to the cargo and the device is given to cargo. It is delivered to door by the cargo. Cargo is waited approximately for 4 hours. Device goes to the supplier. The device is delivered from the supplier after the calibration processes are done. Sometimes we receive and sometimes the cargo receives the delivery. Then, the device is delivered to the Calibration Factory. A new label is regulated in the Calibration Factory according to the documents given to them by the company from the outside. The outside companies don't give time, they give data. When the device arrives, it is reset and given with that day's label. For example, if the device is not used for 45 days, that time period is not included in the waiting device. In Calibration Factory, a certification process is done to the received device. After introducing the received device to the system, it is seen activated. Device is delivered to the factories where they are received from or factories are waited to come and take it. This waiting period is a highly serious one and it is the period of customer's coming and receiving it.

On the other hand The Department of Finance, , maximizes the activity in management of investment, fund and budget by offering planning between customer

and supplier, budgeting and monitoring, and by presenting a reporting that management will need in the frame of finance-effective-profit with systematical record and reporting. If the device is not sent to domestics or abroad for calibration and repaired in the Calibration Factory in itself, our process will be in this manner; the equipment which comes in the calibration time is reported through e-mail to the related factory. The related factory prepares the equipment. Equipment is brought to the Calibration Factory. As a pre-control, the equipment is checked whether it works or not. If the equipment is defective, a malfunction form is filled. Equipment is put on the malfunction shelf. Waiting period for equipment starts. If equipment is not malfunctioning, an equipment admission record is done. Calibration is planned and equipment is taken to the section of inactive. Waiting period for equipment starts. For malfunctioning or non-malfunctioning equipment whose pre-control has been done, it is checked whether the equipment can be activated or not. If the equipment can't be activated, it becomes useless and the equipment is disposed. If the equipment can be activated then it is sent to the calibration. Calibrated equipments are placed on the active shelf. Waiting period for equipment starts. It is put on the malfunction shelf. The process is completed when the equipment is sent back to the factory.

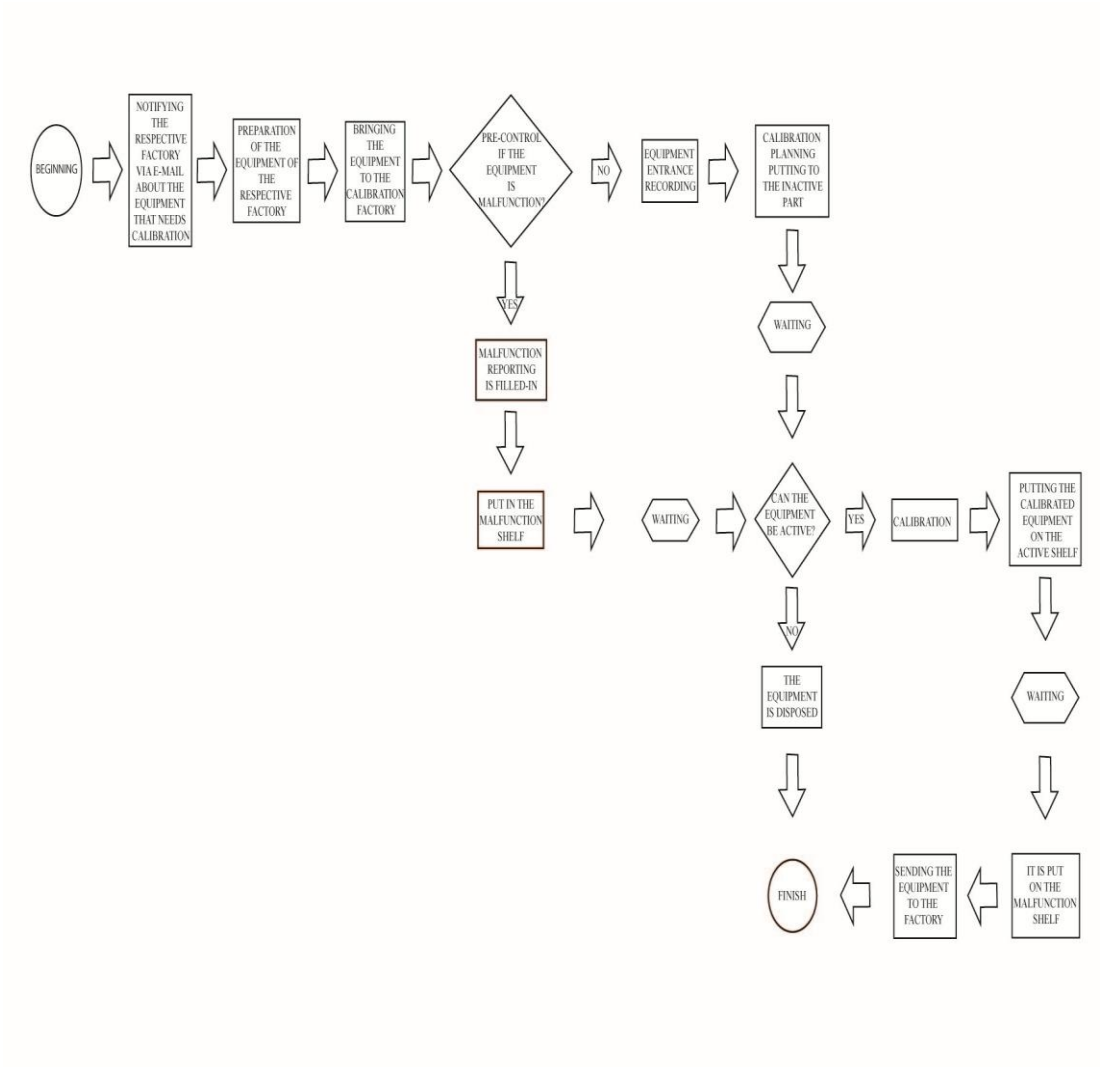


Figure 4.1: Flow Scheme of Calibration Factory

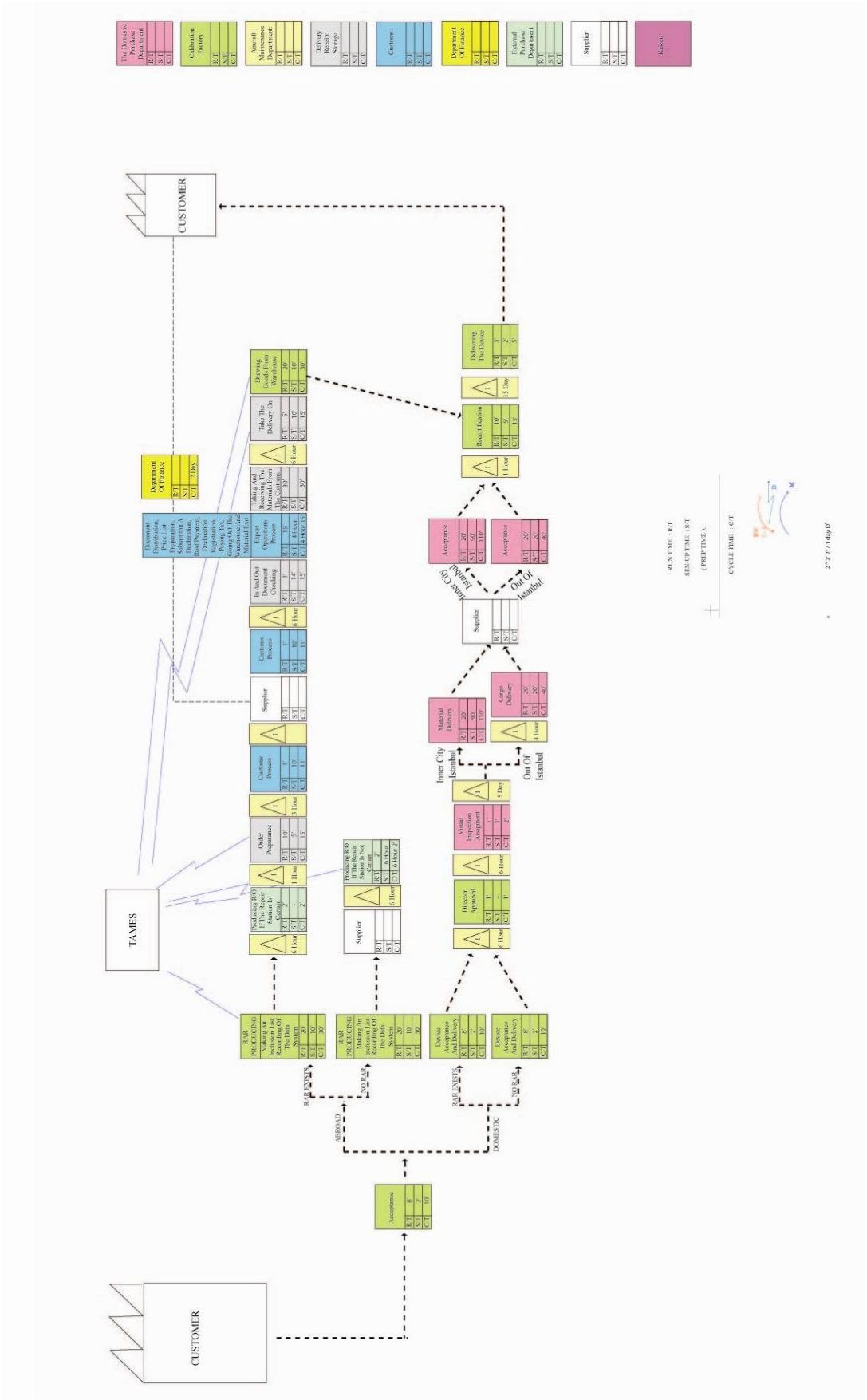


Figure 4.2: Current State Map

4.5.2 Improvements and VSM Plan

Some Kaizen studies have been represented on future state map. That kaizen studies are constantly supported by training activities within management is thought to be a separate and important mission for business managers.

The Kaizen items and their solution proposals about processes:

• Documents from The Domestic Purchase Department cannot be followed. All the calibrations need to be done with RAR for this situation.

• If RAR is going to be produced newly there may be lots of problems about communicating with relevant firm. For this, lists of firm's responsible people need to be made.

• According to the regulation approval in RAR is in directory. Operations cannot be made without the directory's approval. Directory revise must be done. RAR's approval must be done without the directory's approval.

• While the workshop is producing RAR, repair order is not given automatically from shipping department. If the station is not known where the device will be repaired, the repair station information is not given by the repair chieftainship. While workshop is producing RAR, repair order must be given automatically from shipping. If the station is not known where the device will go for repair, the repair station information must be given and approved by repair chieftainship.

• Some problems occur in the process of The Domestic Purchase Department, assignment and control. Recruitment must be done in the process of The Domestic Purchase Department, assignment and control.

• There is automatically no message sent to the relevant workshop as soon as the Calibration Factory is certified. In this situation a message must be sent automatically to the relevant workshop jus as Calibration Factory is certified.

• To relevant workshop on repair’s sending equipment to shipping, automatic message is not sent to workshop doing RAR as soon as repair order is produced. To relevant workshop on repair’s sending equipment to shipping, automatic message must be sent to workshop doing RAR as soon as the repair order is produced.

• There is no introductory sticker for equipment with calibration. There must be introductory stickers for the equipment with calibration.

•The company cannot provide the device’s traceability from the start till the end of calibration process. The company must provide the device’s traceability from start and until the end of calibration process. A table which is fed automatically must be generated for each device from TAMES in TAMES Analyzer.

• There is no separate place in the shipping department. A separate place must be made for the shipping department.

• There is no barcode system in the company. In this situation a barcode system must be established and adopted to all the units of company.

• Device which has come back to the calibration factory after being calibrated waits so long on the shelf to be picked up by the user workshop. If the device which has come back after being calibrated is not picked by user workshop, an automatic mail must be sent to the top supervisors.

• There is no department including one person from each unit to follow the calibration process. A cell unit must be established.

• Checklist is not produced for following of external calibration process. To follow the external calibration process a checklist must be produced in TAMES Analyzer.

• Document and device are not sent at the same time in domestic repair requirement. Document and device must be sent at the same time in domestic repair requirement.

• There is not a separate department for tester came for shipping. A separate department for tester came for shipping must be established.

• The company does not have an agreement with a firm which calibrates abroad or follows this process. The company must make an agreement with a firm which calibrates abroad and follows this process or fastens the turns in payments annual or periodic without paying cash.

• Time between the date of entry to directory of repair documents' (cash payment) coming to Department of Finance and the starting date of the bank transaction is very long. Time between the date of entry to directory of repair documents' (cash payment) coming to Department of Finance and the starting date of the bank transaction must be shortened.

• There are no precautions against the risks of damaging and getting lost of devices sent to abroad for calibration. Devices sent to abroad for calibration must be insured against the risks of damaging and getting lost.

• When the arrangement is made how much money has been paid for devices sent to abroad for calibration in 2009-2010, it must be calculated to understand how much income has been got.

• Separate documents must be sent to B gate customs for each device going to domestic calibration. Approved list must be sent to B gate customs for each device going to domestic calibration.

• Device documents travel a lot in the company and the transactions on devices conclude late in the Supplier because devices going abroad for calibration are paid cash. In supplier an agreement must be made with a firm with wide range of services and calibration opportunities and devices which will be calibrated must be sent abroad with this agreement.

• Equipment room and Component workshops send devices to be repaired and calibrated. Calibration Factory either repairs devices there or fills shipping or RAR. Devices that cannot be repaired in Calibration Factory are sent to another firm. Devices are not always sent to relevant firm. For example, even though

there is an agreement between “A” firm, while device is about to be sent this firm, suddenly the firm changes and it is sent to” B” firm. If the device was sent to “A” firm there would be no problems of cable etc. There occur problems in devices sent to” B” firm. We can accept this ‘A’ firm as a hub of “B”, “C”, and” D” firms. When the device has been sent to “D” firm, if it is wanted to send back to the “A” firm, the “A” firm makes it a problem for this firm. The “A” firm wants the device to be sent its firm first. When the agreement has been made with “A” its going to “D “hinders plans. We must make agreements with only one firm and send devices to it.

• There is a waste of time in shipping or customs and devices may wait there for a long time. Depending on the device the time of going from workshop to the customs is a problem.

• Testing devices must be customized by a person who is expert on this matter. While purchasing a device it is important to consider both device’s transaction and calibration operation.

• There is no agreement on according to what all devices sent to calibration are calibrated. There must be an agreement on according to what all devices sent to calibration are calibrated.

• There is no system showing the date when RAR and Repair Order (RO) are produced. There must be a system showing the date when RAR and Repair Order (RO) are produced.

• In delivery process, the required information is not sent to the customer, the workshop and the calibration factory. Information on materials of AOG (aircraft on ground) is sent but it is wanted to have this information for all materials.

• There is no unit which controls the calibration unit and can be assembled any time it is wanted. There must be established a unit which controls the calibration unit and can be assembled any time it is wanted.

• There is no Calibration portal in the company. Calibration portal must be established.

• Traceability of device from the beginning of shipping until the end cannot be provided. Traceability of device from the beginning of shipping until the end must be provided. A link must be provided in TAMES Analyzer on this issue.

• There is no budget for the test measuring device. A budget for the test measuring device must be created.

• Nothing in system is online. Everything must be online. We can see all devices sent to Calibration Factory via online program on .Clicking on the device, information gathers in TAMES and if you know your own equipment and can access the program, you can see all the information available in TAMES and in which stage your device via the program.

A proposed plan to achieve the future state of the process has been given. Carrying out Kaizen studies represented on the future state map as soon as possible will fasten the journal of lean production of the company.

4.5.3 Seven (7) Methods

While determining the Future State Map, 7 different method equipments are used, which are also used in every workshop. In this equipment, it is expected from everyone to offer a new method for future state without bounded by the current state. It is expected from these methods to determine what the new process will be like and how the control mechanism will work. The elements that can fasten the process and the control devices, Preparation, Transportation, Coordination, Speed, Time and Quality are determined as key words. From the newly proposed methods, the most suitable and effective one is chosen and the future state map is formed.

4.5.4 Future State Map (FSM)

After completing all the kaizen items, the new process will be as in the Future State Map. Device comes to the calibration factory from the customer, in other words it comes from the user factory. If the device will be sent domestic or abroad for calibration after it is admitted because the ability of calibration factory is not good enough for this device, we face with two situations. Calibration factory forms the domestic repair requirement. It delivers the device to the cargo by itself. Then, the

device goes to the supplier. Coming from the supplier it is received by the calibration factory from the cargo at the B gate. The device is certified. When the device comes to the calibration factory, an automatic message regarding the competitor of device to the Calibration factory is sent to the factory. Then, it is delivered to its factory or from the factories receives back the device by themselves.

RAR is formed in the devices that have been sent abroad. Inclusion is prepared, and it is recorded in the database. As in the current situation, External Purchase Department (Chief of Repair Follow-up) forms the RO. Because of the fact that the Calibration Factory will be informed through automatic mail system when RO is formed, the Calibration Factory can send the device to delivery at that moment, because the device stays physical at the Calibration Factory. When shipping order has been issued in Delivery, it goes to the output custom. Documents are prepared in customs, while writing of the declaration and registration is done; material from delivery goes to the cargo. Device goes from there to the supplier and in the return from the supplier it goes to the return customs. In the Chief of Repair, repair in and out documents are checked. Distribution of documents, issuing the tariff, preparation of the declaration and the RUSF payment is done. After the control, material is received from here, customs by the delivery. Material goes to delivery. After the Delivery, the Calibration Factory takes the material from the warehouse, certifies the device and delivers it to the factory.

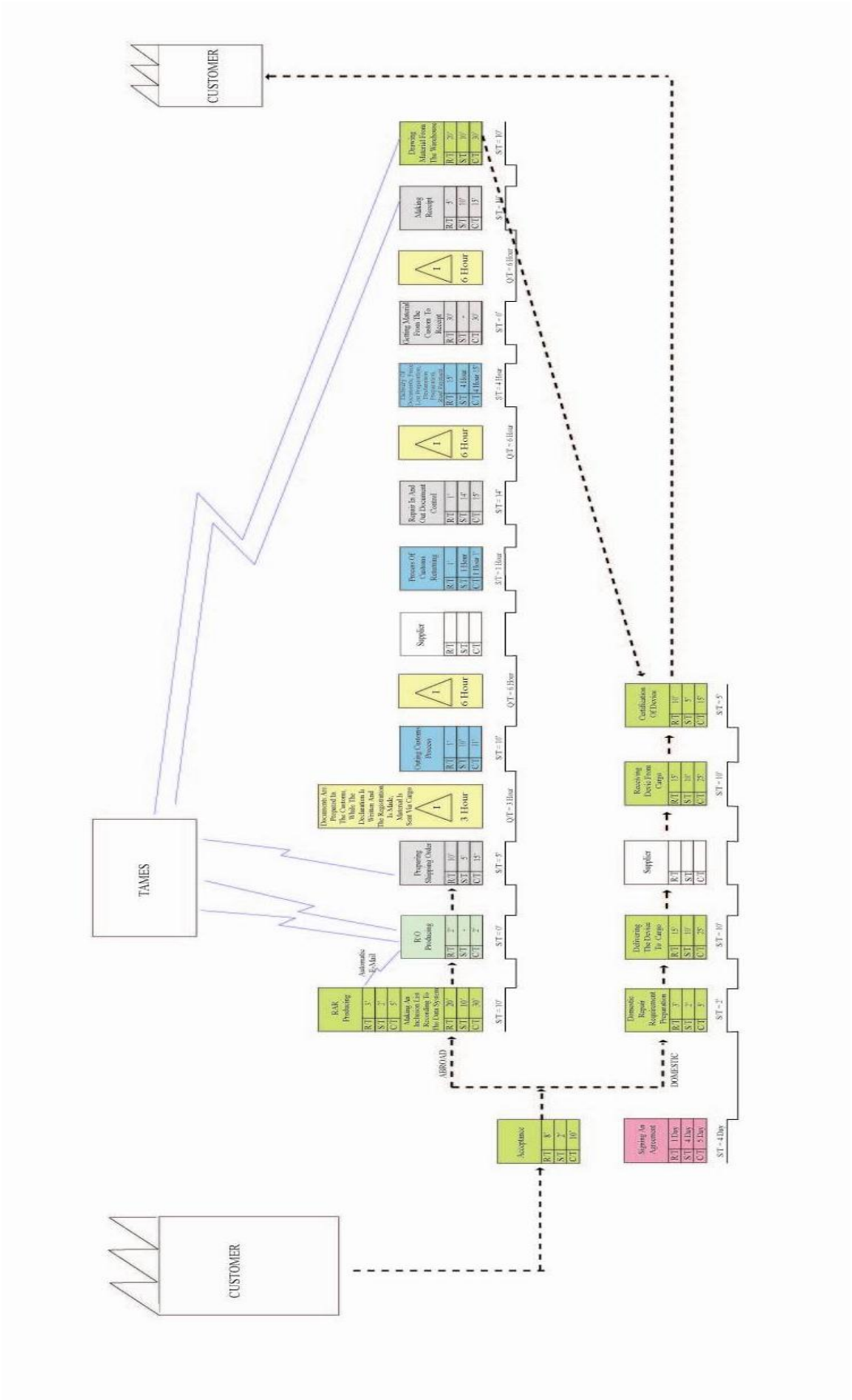


Figure 4.3: Future State Map

4.5.5 Results

This workshop has been established in order to examine the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices to find the units where delays are happening in this process, to improve this process for at least %10 by working between the calibration factory and other units. In this practice, the bottlenecks related to this process are, the company's working with other companies and facing difficulties in logistic process except America. Workers' requirements from the company related to the process are the formation of a fast work flow by working with only one vendor. Non-value-added (NVA) times consist of Setup Time and Q Time's sum. Man Hours (MHRS) because only one man is working cycle time is used. Workshop Man Hours (MHRS) has been taken into account as 10 men and 3 days. All process steps have been counted. The total number of the domestic and abroad calibration devices is 800. Right after the device has been delivered to the calibration factory, everything is asked to this unit. Because calibration factory is not fully dominant in the processes of repair, purchase and finance departments, it cannot give clear answer to the other unit's questions related to the department which the device is in.

On the condition that we have adapted the Future State Map in the company, Run Time will be %18 domestic, %6 abroad, our Setup Time will be %85 domestic, %16 abroad. Cycle Time is %68 domestic, %13 abroad. Our total waiting period (Q Time) is %100 domestic, %82 abroad. Total time elapsed (Lead Time) is %99 domestic, %83 abroad. And the Non-value-added (NVA) times will be %99 domestic, %79 abroad. Total Man Hours is %68 domestic, %12 abroad. Process steps are %59 domestic, %50 abroad. The man hour time used in this workshop, will amortize itself in 2,4 months if this workshop is applied. In the current situation the main target is to determine how many days to reduce from the 61 days of the total process. In order to shorten this process, it is decided that the company will make an agreement with a firm which makes calibrations abroad or can follow this process, in order to speed up the returns in payments annual or periodic without paying cash and to do the works through that company, in another words the agreement will be made with the External Supplier.

In the new state, after the supplier's process has been removed, while Lead time is 23 days in domestic excluding the supplier, in the future state it has been reduced to

1 hour, and abroad Lead Time has been reduced to 27 hours from 27 days excluding the supplier. We exclude the supplier because we don't know in how much time the company that works for us does the transactions. The 23 days that pass during the output of the device from the calibration factory and it's delivery to the customer after it arrives to the calibration factory, passes in the company. If "urgent" is not written on the devices, the past 23 days are the times period for circulation of the documents only. When the device arrives to the calibration factory, the TAT period (average waiting period after arriving to the calibration factory) starts. Device is sent to the Eskişehir, and except the repair period in Eskişehir, only 23 days passes. The device arrives to the calibration factory and when It takes for 15 days to send the device for calibration to the company, to be received by the factory after comes back to the Calibration factory,.

In order to reach Lead Time abroad, it has been decided to do studies, researches in the beginning of the year, prepare the list, agreements to be done between the units and prepare declarations for calibration. Because the agreements and the studies will take some time, the results of this workshop, in other words, the data will be accessible in 6 months after studies and agreements required for the future state have been done,.

Table 4.4: Target Domestic

	BEFORE	AFTER	CHANGE %
NVA-UN	23 day 2 hour 12 minute	29 minute	99
LEAD TIME	23 day 3 hour 18 minute	1 hour 23 minute	99

Table 4.5: Target – Domestic Calibration

	CURRENT STATE	FUTURE STATE	% CHANGE
RT	1 hour 6 minute	54 minute	18
ST	3 hour 12 minute	29 minute	85
CT	4 hour 18 minute	1 hour 23 minute	68
QT	22 day 5 hour	0	100
***LT	23 day 3 hour 18 minute	1 hour 23 minute	99
****NVA=ST+QT	23 day 2 hour 12 minute	29 minute	99
TOTAL MANIIOURS	4 hour 18 minute	1 hour 23 minute	68
PROCESSING STEPS	17	7	59
THE ONE JOINING THE WORKSHOP	180 manhours	ROI= (50DEVICE X3MANHOUR)+750(DEVICE X 1 MANHOUR)=2.4 MONTH	

Table 4.6: Target – Abroad Calibration

	CURRENT STATE	FUTURE STATE	% CHANGE
RT	1 hour 53 minute	1 hour 46 minute	6
ST	6 hour 1 minute	5 hour 4 minute	16
CT	7 hour 54 minute	6 hour 50 minute	13
QT	19 day 4 hour	21 hour	82
***LT	27 day 4 hour	27 hour 50 minute	83
****NVA=ST+QT	20 day 4 hour	26 hour 4 minute	79
TOTAL MANHOURS	7 hour 54 minute	6 hour 50 minute	12
PROCESSING STEPS	24	12	50
THE ONE JOINING THE WORKSHOP	180 hour	ROI=2.4 MONTH	

4.6 QUALITY FUNCTION DEPLOYMENT METHOD

Quality function deployment (QFD) is a methodology for translating customer wants (WHATs) into relevant engineering design requirements (HOWs) and often involves a group of cross-functional team members from marketing, design, quality, finance and production and a group of customers. The QFD team is responsible for assessing the relationships between WHATs and HOWs and the interrelationships between HOWs, and the customers are chosen for assessing the relative importance of each customer want (Chin et al., 2009).

Other QFD matrix parameters that shall be included are the importance weight of customers' requirement, competitive assessment, relative and absolute weight of customers' requirements and technical specifications, technical difficulties and target (Deros et al., 2009).

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 (Yılmaz, 2009).

This is a method created to link product and service design decisions directly to customers. Wants and needs. QFD is also known as the house of the quality (HOQ). HOQ is designed to deploy customer input throughout the design, production, marketing, and delivery facets of a given product or service. In a typical QFD application, a cross-functional team creates and analyzes a matrix linking customer wants and needs to a set of product and service design metrics that the company can then measure and control (López et al., 2005).

QFD analysis is a step-by-step process. The various steps are,

Step 1: Determining the voice of the customer (customer needs): Voice of the customers (VOC) is a direct retrieval of the customer requirements. This could be done by opened or closed interviews or surveys. It is important not to lead the customers to the desired answers but to allow them to express to the company what they really want (Gonza´lez et al., 2003).

Quality Function Deployment (QFD) proposes to take into account the "voice of the customer," through a list of customer needs, which are (qualitatively) mapped to technical requirements in House One (Aungst et al., 2002).

To collect customer needs for the product (or customer requirements, customer attributes) called WHATs (Kongprasert et al., 2009).

Step 2: Determining the priority structure of customer needs and preparing the competitive evaluations of customer needs.

The customer plays an important role in determining the relative position of the organization with respect to that of its competitors for each customer need. This competitive assessment of customer needs can be accomplished through survey of customers, which includes questionnaire survey, direct interviews, telephonic interviews and interaction through e-mail (Jnanesh et al., 2008).

Step 3: Develop the customer portion of QFD matrix.

In the development of the house of quality is building the horizontal part of the matrix, which is related to the customer requirements. This step is based on the information analyzed in the previous step and is to be include in a structured way into the matrix. Other information is required such as level of importance, competitor evaluation on these requirements versus our evaluation from the customers, and other ratios (Gonza´lez et al., 2003).

Step 4: Develop the Technical portion of QFD matrix.

The vertical portion of QFD matrix is related to the technical data. Once the customer needs are identified, then QFD team can establish appropriate design requirements that would satisfy those needs. The team for obtaining the target ratings for each design requirement conducts competitive technical assessment. Inter relationships for customer needs and design requirements are established, which are placed at the middle of the technical portion of the QFD matrix. The co-relationship of the design requirements can be examined. The objective is to highlight any requirements that are in conflict with each other. If action on one item will harm another item, this negative effect needs to be resolved. The triangular portion

accommodates these co-relations, which gives the overall QFD matrix the appearance of a roof top. As a result, the QFD matrix is referred as the House of Quality. Column weights can be calculated, by using the customers' importance level in conjunction with weights assigned to the relationship symbols. The resultant number provides a method of judging the relative importance of each of the design requirements. Column weights can serve as an index for highlighting those design requirements that have the largest relative effect on the product. These column weights are entered at the bottom of the technical portion of the QFD matrix (Jnanesh et al., 2008).

Step 5: Analyze the QFD matrix

Last step is to analyze the house of quality. This stage is very important since we will determine which customer requirements will be implemented into the process as technical requirements due to their importance for the customers. There will be some customer requirements that are really impossible or very expensive to implement in the process; therefore, a decision should be made in order to determine which technical requirements will continue in the analysis of the other matrixes of QFD (Gonza´lez et al., 2003).

4.7 DEFINITION OF QFD

Quality must be designed into the product, not inspected into it. Quality can be defined as meeting customer needs and providing superior value. This focuses on satisfying the customer's needs, places an emphasis on techniques such as Quality Function Deployment to help understand those needs and plan a product to provide superior value (Crow, 2002 pg 1; Anıl, 2007).

QFD was first introduced in Japan by Dr. Yoji Akao in 1966. Akao, widely regarded as the father of Quality Function Deployment (QFD), defines it as "a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demands into design targets and major quality assurance points to be used throughout the production phase" (Akao and Mizuno, 1978; López et al.,2005).

In 1967 the Matsushita Electric has grown splitting the function of the product from the characteristics required for the product and the production process. The model did not permit the establishment of the quality of the project (Akao, 1996; Ferreira et al., 2008). QFD was first applied at the Kobe Shipyards of Mitsubishi Heavy Industry in designing of an oil tanker in 1972 (Islam, 2007).

The first book on QFD was published in 1978 by Dr. Shigeru Mizuno in conjunction with Akao. Toyota Auto Body adapted QFD in the late 1970s and made refinements to quality tables. The refined structure of tables became later known as ”the house of quality” matrix. QFD was formally introduced to the USA in 1983. The first case study outside Japan was reported in 1987. Since then, QFD has been used in ever widening circles. The application of QFD to software development began in Japan in 1982, in North America in 1988, and in Europe in 1990 (Zultner,2000 ; Koski, 2003) .

The model has received improvements from studies and applications in different fronts. The model spread to the world and is present in many companies as Xerox, Toyota and Ford. The method allows the deployment of the demands of consumers in standards of operations aiming to satisfy their needs (Ferreira et al., 2008).

QFD is oriented toward involving a team of people representing the various functional departments that have involvement in product development: Marketing, Design Engineering, Quality Assurance, Manufacturing/ Manufacturing Engineering, Test Engineering, Finance, Product Support, etc. (Çelen,2008).

Quality Function of Deployment (QFD) is a tool for designing manufacturing (service) processes in response to customers’ needs by translating what the customers want into what the organization produces. Their purpose was to develop the quality assurance method that would incorporate customers’ needs into the design of a product before it was manufactured. Before the development of QFD, quality control methods were primarily aimed at fixing a problem during or after manufacturing of the product (Islam, 2007).

The nickname of the technique is from Japanese. The meanings of the components are explained by Yenginol (2000). The Japanese characters for QFD are, phonetically, Hinshitsu, meaning “quality”, “features”, “attributes”, or “qualities”,

Kino, meaning “function” or “mechanization”, Tenkai, meaning “deployment”, “diffusion”, “development”, or “evolution” (Doğu, 2006). Akao and Mazur (2003) defined QFD as a method for defining design qualities that are in keeping with customer expectations and then translating those customer expectations into design targets and critical quality assurance points that can be used throughout the production/service development phase (Gonzalez et al., 2007).

Cohen (1995) described QFD as a method for structured product planning and deployment that enables a development team to specify clearly the customer’s wants and needs, and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs (Doğu, 2006).

QFD has been defined as "a system for translating consumer requirements into appropriate company requirements at each stage from research and product development to engineering and manufacturing to marketing\ sales and distribution" (American Supplier Institute, 1989; Suliman, 2009).

Quality function deployment is a process—a method—for planning products and services. It starts with customer needs and wants—the voice of the customer—which become the driver for the development of the requirements for the product or service. The QFD process is best conducted through teamwork, because there are many inputs and decisions involved. This kind of approach tends to remove organizational barriers and effectively links the company to its customers. The organization works more cooperatively, and the new product or service has an increased potential for satisfying its ultimate customers (Day 1993; Koski, 2003).

Quality function deployment (QFD) is ‘‘an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production, sales)’’(Sullivan, 1986b; Chan et al.,2002).

Quality function deployment (QFD) is a cross-functional planning methodology commonly used to ensure that customer expectations or requirements, often referred to as the voice of the customer (VOC) or WHATs, are deployed through product planning,

part development, process planning and production planning. It is a team-based and disciplined approach to product design, engineering and production and provides in-depth evaluation of a product. An organization that correctly implements QFD can improve engineering knowledge, productivity and quality and reduce costs, product development time and engineering changes (Besterfield et al., 2003; Chin et al., 2009).Quality Function Deployment is a design system which designs products or service according to Voice of Customer. It translates customers' needs into technological or feature specifications. To reach perfect products means nothing but to reach exactly what customer needs and wants means everything (Anıl, 2007).

QFD is primarily a people system. Nothing happens without people. Its point of departure is the ``voice of the customers'' (VOC). It also brings together multifunctional teams to work together towards satisfying the customer. QFD also helps to build a partnership between customers and suppliers. QFD can help companies make the key trade-offs between what the customer wants and what the company can afford to build. By concentrating efforts on what will satisfy the customers and the company most, less time will be spent on redesign and modification of the product/process. It helps companies to move from an inspection-based approach to designing quality into products and as such plays a key role in any total quality management (TQM) or continuous improvement programme or implementation. QFD does nothing that people did not do before, but it replaces inconsistent, intuitive decision-making processes with a structured approach. (Bouchereau et al., 2000)

QFD can be used to increase customer satisfaction, decrease delivery date and costs and solving problems for mentioned points (Anıl, 2007). QFD, the voice of the customer aligns the company's resources to focus on maximizing customer satisfaction and minimizing waste. QFD is not just a quality tool, it is a planning tool for developing new products and improving existing products. QFD permits the "voice of the customer", rather than the "demands of management", to allocate company resources and to coordinate skills and functions in producing the final product (Yoji Akao, 1990a; Suliman, 2009).

The successful implementation of QFD requires a significant number of subjective judgments from both customers and QFD team members. Customers are selected for assessing the relative importance of customer expectations or requirements

(WHATs). The QFD team is set up to identify customer wants, map them into relevant engineering requirements, which are often called the HOWs, meaning how the WHATs are to be met, develop the relationship matrix between WHATs and HOWs and the interrelationship matrix between HOWs, and prioritize the HOWs (Chin et al., 2009).

Quality Function Deployment helps development personnel maintain a correct focus on true requirements and minimizes misinterpreting customer needs. As a result, QFD is an effective communications and a quality planning tool (Çelen, 2008). QFD is not only a map for product design. It is also a map for quality improvement for current products. With the House of Quality, a design team could see how a company's product met customer requirements and what the market position of company's product regarding to "qualities" was. This will provide directions for market and quality improvement (Chang, 2002).

4.8 BENEFITS OF QUALITY FUNCTION DEPLOYMENT

• QFD brings the voice of customer into the company supremely. In this way customer needs and wants are prioritized in design process. So expose of goods are successful because marketed products or services meet customer needs and wants. Customers gain products and services as they want quickly.

(www.12manage.com/methods_akao_quality_function_ deployment.html) (Anıl, 2007)

• QFD is a customer-driven process; it creates a strong focus on the customer (Yılmaz, 2009).

• Customer satisfaction (Islam et al., 2007).

• QFD will give you a better product, service, or process than you would have achieved otherwise (Koski, 2003).

• QFD decrease costs. QFD can play a major role in decreasing of operation costs (Cohen, 1995). This is because QFD reduces irrelevant processes as well as reduces a possibility that product design will need to change during the production (Cohen, 1995; Ong, 2003).

• QFD enables low costs and maximum performance in production process (Anıl, 2007).

• 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 (Yılmaz, 2009).

• QFD will give you this better outcome faster than will other methods. Also, this measurement is possible only when the process can be repeated in successive or parallel instances (Koski, 2003).

• The extended part of adjustments and changes are made in the design step. All design decisions are taken at the beginning. Thus company save making a mistake chance in the design process and the expenses that are caused by mistakes (Anıl, 2007) .

• Another benefit of QFD is that it structures experience and information into a concise format (Yılmaz, 2009).

• Fewer engineering changes in the later stage (Islam et al., 2007).

• QFD will give definition to the design process, helping the design team to stay focused and effective, giving team members greater ability to see and understand how they contribute to the design process as well as how to work with customers and other team members (Koski, 2003).

• In product and process design steps, company can save costs because extended part of resources is used at the beginning, in order to realize products and services which meet customer requirements and wants (Anıl, 2007).

• QFD will allow for easy management and peer review of design activities as they progress, with graphical representation of the different sets of information driving the design as well as the linkages between information sets (Koski, 2003).

• QFD can help reducing the product development cycle time because it help reducing error in implementation and redesigning process (Cohen, 1995). In other words, QFD reduces a time-to-market for any particular product (Cohen, 1995; Ong, 2003).

• QFD enables the design group to see events and conditions in different point o views. The problem is solved by evaluating relationships between problems and using statistical methods. Therefore, company can produce more reliable and quality products and services (Anıl, 2007).

• Reduced chance of oversight during the design process (Islam et al., 2007).

• QFD increase revenues .As the final products performed QFD process, tend to achieve the customer satisfaction, the organization will gain a market share and higher revenues (Cohen, 1995 and Han, 2001; Ong, 2003).

When we examine House of Quality and other elements of QFD, it is obvious that QFD is a scientific system which reveals required modifications according to customer requirements. This system consists of design characteristics, customer requirements, benchmarking, cost and sales estimation, product or service design, interaction between design characteristics and relationship between design characteristics and customer requirement. To summarize, QFD is a decision system which decides modifications and target values for a product or design (Anıl, 2007).

4.9 HOUSE OF QUALITY

Quality Function Deployment (QFD) is a set of powerful product development tools that were developed in Japan to transfer the concepts of quality control from the manufacturing process into the new product development process. The main features of QFD are a focus on meeting market needs by using actual customer statements, its effective application of multidisciplinary teamwork and the use of a comprehensive matrix (called the "House of Quality") for documenting information, perceptions and decisions (Lowe et al., 2000).

The QFD matrix used in the case was based on the “House of Quality”. It was developed by Clausing and Hauser (1988), and it drives the marketing people, design engineers, architects and site engineers toward satisfying customers’ desires and preferences (Gargione, 1999). 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 (Yılmaz, 2009).

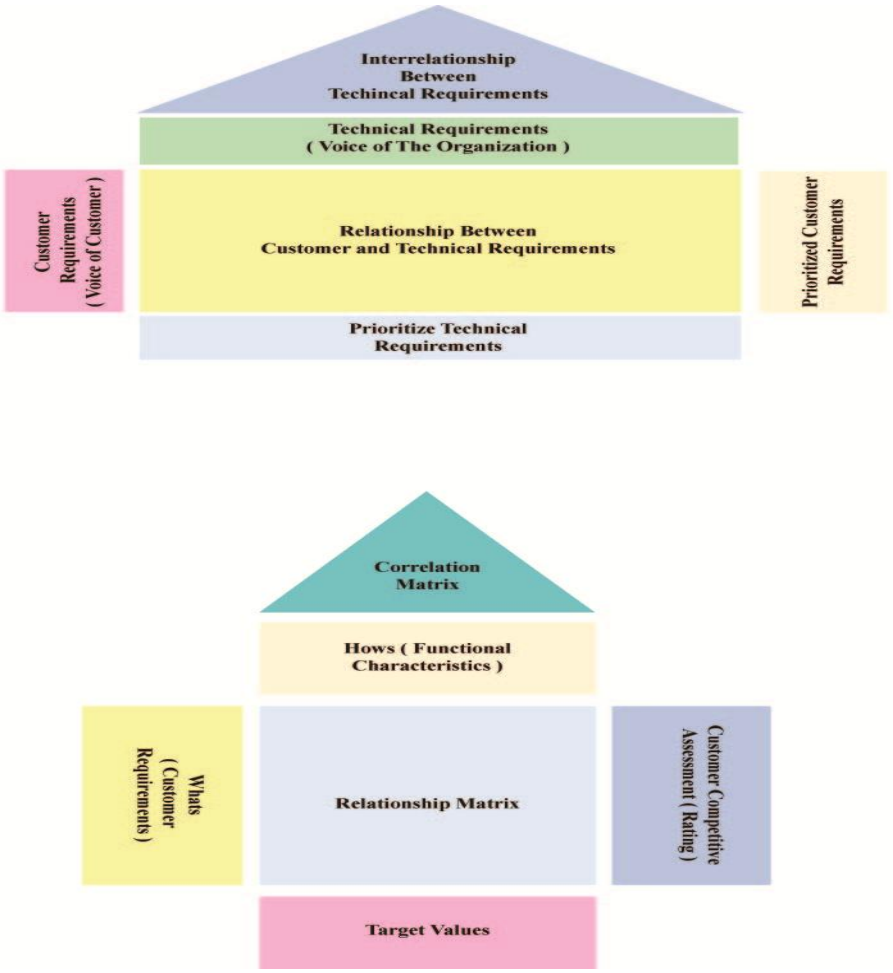


Figure 4.4: General Architectures of a House of Quality

In the above Figure, the exterior wall in the left side is the customer requirements, the listing of voice of the customer, or what the customer expects in the product. On the right side prioritized customer requirements or planning matrix. The ceiling contains the technical requirements. The centre portion of the house is the relationship between customer requirements and technical requirements. The roof of the house is the interrelationship between technical requirements. The foundation of the house is the prioritized technical requirements this is the structure for the house of quality (Jnanesh et al., 2008) .

Another form of expression of the house of quality is as follows:

QFD accomplishes these goals through the use of a design tool that is known as the "House of Quality" (HOQ) as shown in below Figure, the "Whats" room represents the voice of the customer and on the right is a customer competitive assessment that is expressed in form of a rating. The "Hows" room records the functional characteristics of a product including how customer needs can be met. The roof is the correlation matrix room which indicates the positive and negative relationships between the technical characteristics of the product. These relationships can help to generate new alternatives by highlighting areas for improvement in current products (Hauser et al., 1988). After completing the "Whats" and the "Hows" rooms, these relationships can be worked out and expressed in a relationship matrix as indicated in the center of the house. Once the relationship matrix has been completed, the extent to which the product performance will satisfy customers is calculated and is expressed as an absolute score and a score that is relative to the target value (Law et al., 2007).

4.9.1 Customer Requirements

Customer requirements are also known as voice of the customer, whats, customer needs and benefits, customer attributes, or demanded quality. Customer needs, usually collected by focus groups or individual interviews should be expressed in customers' own phrases (Karsak et al., 2002).

Day (1993) presents approaches for obtaining the voice of the customer: focus groups, interviews, mail questionnaires, product clinics, and observations. Data can be gathered from multiple sources, for instance, from direct interviews and customer complaints received by product-support department. The questioning should be continued until the root want is discovered; it will be too late once the respondents have gone and the company personnel are back-home trying to figure out what the customer meant (Koski, 2003).

According to Griffin and Hauser (1993), individual one-to-one interviews may be more cost effective than focus groups, and at least 20– 30 customers should be interviewed to obtain 90–95% of all the possible customer needs. Mail or telephone surveys should be avoided due to the difficulties in controlling the scope of responses (Karsak et al., 2002).

To identify the basic customer needs is essential. 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. Not all customer needs are equally important. 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 (Yılmaz, 2009).

Satisfaction increases when expectations are met, while dissatisfaction arises when they are not. It is very important to know the real customer needs. Finding the root-wants of customers is essential to the survey process. Customers tend to mix needs, solutions, and problem concerns; therefore asking “why” is important (Koski, 2003).

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 (Yılmaz, 2009).

4.9.2 Technical Requirements

Technical requirements are also known as voice of the organization, Technical responses, Hows, Functional Characteristics, Response to Customer Needs Technical responses identify the technical specifications or engineering characteristics. Going from user requirements to technical specifications involves translating from qualitative requirements to quantitative measurable characteristics (Halog et al., 2000).

Cohen (1995) defined technical characteristics as the term used for the internal, technical language an organization uses to describe its product or service (Doğu, 2006).

The aim of the house of quality is to design products to fulfill the requirements of the customers or to improve current designs. In an application having this target the most important point is to turn the customer requirements into technical definitions that can be used in the engineering stage. Every definition in this part must be correlated with at least one matter in the customer requirements part. This part of the house of quality is really important because, that the engineers can fulfill the customer requirements truly depends on the suitably made technical definitions (Kurtay, 2005).

The technical requirements are represented in a language that the company uses to describe its products for design, processing, and manufacture. The technical requirements must not represent solutions. Each technical requirement should be worked on to satisfy a voice, be measurable and global in nature, and should not imply any specific design intent (Day 1993; Koski, 2003).

“HOWS” can consist of processes, people, functions, facilities or methods. However, in order to be determined they require knowledge of a whole organization. In this point it is very important to perform a much disciplined teamwork. Because, solving a problem requires different ideas and experiences (Guinta and Praizler, 1993).

4.9.3 Relationship Matrix

Relationship between customers wants and technical characteristics are given on the relationship matrix. Relationship should be between strong positive relationship and strong negative relationship. Sometimes there can be no relationship between customer needs and design characteristics. That area shows which characteristics should be changed in order to satisfy customer requirements (Anıl, 2007).

After identifying each of the engineering features "how" that affects one or more "why" defined the relationships between each "what" and every "how", taking into account what the relationship is improving every "what" if works in the "how" question (Gómez, et al.,2010). After completing the “Whats” and the “Hows” rooms, these relationships can be worked out and expressed in a relationship matrix as indicated in the center of the house (Law et al.,2007).

The team should work in columns, looking at each technical requirement and asking: “Would working on this technical requirement help to satisfy this customer requirement?” The relationship symbol is written in the intersection cell. After finishing with the requirements, the team should review the relationship portion of the matrix. There should be no rows or columns with no relationship symbols or with only weak symbols (Koski, 2003).

Global symbols are usually used in House of Quality to show these three results. The symbols, their meanings, and their numerical equivalents are as shown in Table (Doğu, 2006)

Table 4.7: Global Impact Symbols

	No Relation/Contribution	0
△	Weak Relation/Contribution	1
○	Moderate Relation/Contribution	3
◉	High Relation/Contribution	9

To build the relationship matrix between hows and whats, it is necessary to establish if relationships exist between every what and every how. All relationships are categorized such as either strong, medium, or weak. A score of 9 is used to indicate a strong relationship between whats and hows. A score of 3 signifies a moderate relationship and a square or 1 signifies a weak relationship between them. The matrix in Table shows all relationship between customer requirements and technical requirements (Zaim et al., 2002).

Although numeric values can be used, the relationships are typically indicated using symbols. Usually a double circle or a filled circle is used for a strong relationship, a single circle for a moderate relationship, and a triangle for a weak relationship (Koski, 2003).

4.9.4 Correlation Matrix

Correlation Matrix is also known as Interrelationship Between Technical Requirement, Correlation, Technical Correlations, Technical correlation matrix.

Technical correlations, is half of a square matrix, split along its diagonal and rotated 45º. Mazur (2003) defines the technical correlations as the "roof" since it resembles the "roof" of a house, the term "House of Quality" has been applied to the entire matrix structure. Technical Correlations contains the development team's assessment of the implementation interrelationships between elements of the technical response (Doğu, 2006).

The technical correlation matrix is used to aid in developing relationships between customer requirements and product requirements and identifies where these units must work together otherwise they will be in a design conflict (Tapke et al., 1997).

The correlation matrix is probably the least used room in the House of Quality; however, this room is a big help to the design engineers in the next phase of a comprehensive QFD project. Team members must examine how each of the technical descriptors impacts each other. The team should document strong negative relationships between technical descriptors and work to eliminate physical contradictions (Ontiveros et al., 2001).

The following symbols are used to represent what type of impact each requirement has on the other. These symbols are then entered into the cells where a correlation has been identified. The objective is to highlight any requirements that might be in conflict with each other (Tapke et al., 1997).

S = Strong positive

P = Positive

N = Negative

X = Strong negative

The roof of the House of Quality shows the impact of work on one Technical Characteristic on the status of other Technical Characteristics. The roof can show the existence and nature of design bottlenecks (Day, 1997; Doğu, 2006).

According to Step-By-Step QFD by John Terninko, asking the following question when working with this part of the House of Quality helps to clarify the relationships among requirements: "If technical requirement X is improved, will it help or hinder technical requirement Z?" (Tapke et al., 1997).

The roof is the correlation matrix room which indicates the positive and negative relationships between the technical characteristics of the product. These relationships can help to generate new alternatives by highlighting areas for improvement in current products (Law et al., 2007).

The objective is to highlight any requirements that are in conflict with each other. If action on one item will harm another item, this negative effect needs to be resolved. The triangular portion accommodates these co-relations, which gives the overall QFD matrix the appearance of a roof top (Jnanesh et al., 2008).

Many technical requirements are related to each other so working to improve one may help a related requirement and a positive or beneficial effect can result. On the other hand, working to improve one requirement may negatively affect a related requirement. One of the principal benefits of the Roof is that it flags these negative relationships so they can be resolved. If these issues aren't settled satisfactorily, some aspects of the final product will dissatisfy the customer (Tapke et al., 1997).

Working to improve one requirement may negatively affect a related requirement. Unlike technical requirements that should be generic and non-design-specific, the determination of co-relationships requires that a specific design is considered. The tradeoffs are entered into a triangular matrix on top of the technical information table. Each requirement is compared to others one by one (Koski, 2003).

Sometimes an identified change impairs so many others that it is just simply better to leave it alone As a result, improving one of them may actually cause a negative impact to the other (Tapke et al., 1997).

4.9.5 Planning Matrix

By Planning Matrix, it is provided that the company can make a benchmark between its own products and the competitors' products. It has a great significance in seeing the company's own place in the market (Arı, 2006). Planning matrix is also known as Prioritized Customer Requirements, Customer Competitive Assessment, Rating.

Planning matrix may contain three main types of information: quantitative data that indicate the relative importance of the wants and needs to the customer; the customer's satisfaction levels with the organization's and its competition's current offerings; and strategic goal setting for the new product or process (Halog et al.,2000).

In the planning matrix which is placed in the right side of the House of Quality, company evaluates its and competitor's situation of satisfying the needs of their product (Savas and Ay, 2005).

The main purpose of the planning matrix is to compare how well the team met the customer requirements compared to its competitors. The planning matrix shows the weighted importance of each requirement that the team and its competitors are attempting to fulfill. Customer ratings, typically ranging from 1 to 5, are given to each company under each requirement. The customer ratings are combined with the weighted performance of each demand to produce an overall performance measure for the companies. The planning matrix is a part of the "House of Quality" matrix (Tapke et al., 1997).

In planning matrix the column "Today" shows how customers perceive company's products within their requirements (Yenginol, 2000). The scale is that "1 is the worst and "5" is the best". The columns "Competitor A" and "Competitor B" show how customers perceive the nearest competitor manufacturing the same products in the market (Arı, 2006).

The column "Target", however, is how the "company" wants to be perceived within the company's current situation and how the competitors are perceived by the customers. While determining the target it is necessary to check the importance degree and look the relative point given to the customer requirements by the customers.

Because, if the importance given to a requirement by the customer is low, the target may not be determined high enough to reach the competitors, even though the company perceived is perceived worse within this qualification (Yenginol, 2000).

The "improvement ratio" column can be calculated by dividing the target value by the current value (Koski, 2003). In the column "Sales Point" it is seen if providing a progress in the customer requirements in lines also creates a progress in sales (Yenginol, 2000).

The Sales Point column contains information characterizing the ability to sell the product or service, based on how well each customer need is met. Sales Points do not carry as much weight as other factors in the, Planning Matrix, such as Importance to Satisfaction Performance Goal. Not all customers needs represent sales opportunities (Doğu, 2006).

Table 4.8: Common Values Assigned for Sales Points

Value	Meaning
1	No sales point
1,2	Medium sales point
1.5	Strong sales point

The analysis of customer requirements is concluded with calculating weights for each requirement. This weight is given by multiplying the customer importance column by the improvement ratio and sales point factor. Typically the results are also normalized so that the sum of weights equals 1 or 100 (Koski, 2003).

In the column "Percentage importance degree", however, is found by normalizing the values in the "Importance Point" column. Thus, every Importance Point that belongs to customer requirements is divided to the sum of the Importance Point column. So, percentage importance within the customer requirement is found (Yenginol, 2000).

Planning matrix has a great importance in terms of the fact that the company may see the product's place in the market (Doğu, 2006).

4.9.6 Technical Matrix

Technical Matrix are also known as Target Values,Prioritize Technical Requirements, Technical Properties Matrix. Technical matrix is used for the new design for innovative systems or techniques. Targets are set for all control parameters that determine the new design along with cost, technical difficulty (risk), and relative importance of achieving each target. This provides management with a valuable means to direct resources by showing the experts' best estimates of the costs and benefits of each improvement in the product or current system design. It also allows producers to evaluate their existing product lines against competitors using technical measures (benchmarking)(Halog et al., 2000).

Technical benchmarking part is the matrix which is created in order to see the effects of technical requirements' on different products in the market. As in the planning matrix the question in this part of the matrix is to compare the technical requirements with the competitors, prioritize the products between each other and to provide data in determining the target (Savas and Ay, 2005).

The technical properties matrix uses specific items to record the priorities assigned to technical requirements. It also provides a technical performance achieved by competitive products and the degree of difficulty in developing each requirement. The final output of the matrix is a set of target values for each technical requirement to be met by the new design. In some cases, organizations are not able to create the most optimum design because of constraints related to cost, technology, or other related items (Tapke et al., 1997). The team can set goals or target values for each technical requirement. These goals—the "how muchs"—are stored in the bottom part of the QFD matrix (Koski, 2003).

4.10 AN APPLICATION OF QFD IN CALIBRATION FACTORY

4.10.1 Establishment of a House of Quality for Model Business

The Aircraft MRO Company is a business which has a quality consciousness. The main target of the company is to meet the customers' requirements completely and to reach an sufficient quality level.

When the QFD application is mentioned to the crew, it is met with an interest along these lines: "How can we apply this approach?", "By applying this approach what kind of advantages the company will gain?"

In the forming of the product planning matrix, first of all the "what" part will be acquired and later the "how" part will be determined. As it is told in the other chapters before, product planning matrix starts with the determination of the "what" part which shows customers' requirements and needs. Later, the "how" part is formed which symbolizes the technical characteristics that enables to meet with customers' requirements and needs. After the forming of the "How" and the "What" parts, and the parts "Relations" and "How much", the product planning matrix will be completed and the phase of transferring the parts will be started.

4.10.1.1 Forming of the Customer Requirements Part

Forming the customer requirements part is composed of determining the customer requirements and needs and studies of determining the degrees of importance of the customer requirements and needs.

4.10.1.2 Determination of the Customer Requirements and Needs

In order to be able to determine the customer requirements and needs, focus group study has been done in practice. The main target of using a focus group is to acquire some demands and requirements for the customers and get them from the customers which the management does not think. Therefore, it is possible to acquire more creative ideas from customers to meet their requirements and needs.

Focus group study has been done with 10 different people from 8 different units. These units are Domestic Purchase Department, Calibration Factory, Aircraft Maintenance Department, Delivery Receipt Storage, Customs, Department of Finance, External Purchase Department and the Supplier. In order to get more creative results from the practice, the focus group has been composed of working people from different education levels. The focus group has been composed of people who are constant customers of The Aircraft MRO Company and it has been reached to those people through the Process Improvement Management.

The focus group meeting has been held in the Process Improvement Management of the Aircraft MRO Company. To get the answers that can meet their requirements and to take their opinions, the question of "What are the qualities you look for in the process of the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices?" has been asked each of them. It is understood from the comments and conversations during the meeting that, in the subject of the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices, the things that come to mind are Delivery on Time, Quality, the Lowest Cost, Less Communication, Service and Guarantee after the Service:, Product Tracing, Unproblematic Delivery of the Product, Insurance of the Product, Door-to-door delivery of the Product.

As a result of the focus group meeting, needs and requirements that are most emphasized by users for "the process of the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices" have been classified as it can be seen below. After the requirements for the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices have been examined it can be said that there is no creative and different opinions beyond requirements. But when the focus group has been forced to create different opinions, they have come up with some interesting ideas. For example, making an agreement with the external supplier and doing business through that company, and The Aircraft MRO Company's establishing external supplier company, are some of those ideas. Unfortunately, because it requires too much time and finance to research whether these ideas are going to be realized or not by the company, it has been decided to improve the current service instead of a new service application while determining the customer requirements in QFD application.

Also, when the information gained from the focus group has been presented to the managers of the Aircraft MRO Company, it has been accepted that those ideas define the services of The Aircraft MRO Company completely.

Table 4.9: Customer Requirements for "the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices"

	Customer Requirements
Delivery Time	Delivery on Time
Quality	Quality
Cost	The Lowest Cost
Customer Relationships	Less Communication
	Service and Guarantee After The Service
	Product Tracing
Reliability	Unproblematic Delivery of The Product
	Insurance of The Product
Service Network	Door-to-door delivery of the product

4.10.1.3 Determining the Importance Degree of the Customer Requirements and Needs

Focus group study is a study that is done in order to determine the customer requirements and needs. In order to determine the degrees of importance of these customer requirements and needs, the group study has been done. AHP (Analytic Hierarchy Process) is a method used in determining the degrees of importance of the customer requirements. However, because the study we have done is not such a complex one the AHP method has not been used. For this, a group of 8 people has been asked to place the determined customer requirements and needs in a scale of 1 to 10.

It has been seen that all the degrees of importance given to every customer requirement varies from one person to another. In order to state this variety as a value,

the arithmetic average of all degrees of importance given to every customer requirement have been calculated and the degrees of importance of customer requirements determined.

As a result of the study, the determined degrees of importance of customer needs are as follows:

Table 4.10: Customer Requirements Table

	Customer Requirements	Importance Degree
Delivery Time	Delivery on Time	10
Quality	Quality	9
Cost	The Lowest Cost	7
Customer Relationships	Less Communication	3
	Service and Guarantee After The Service	8
	Product Tracing	5
Reliability	Unproblematic Delivery of The Product	9
	Insurance of The Product	5
Service Network	Door-to-door delivery of the product	6

Because the study used for determining the degrees of importance of customer requirements consists of 8 people it might not give us the exact customer requirements approach. However, because this study is seen as a practice test, this has been accepted a sufficient one.

4.10.1.4 Competition Evaluation for Customer Requirements (Forming of a Planning Matrix)

In order to do competition evaluation for customer requirements, benchmarks are made with the best companies in the MRO sector and the model company. According to our studies, a number of competitor companies have been determined suitable to benchmark for our evaluation. However, because the study is a practice and

in order to ease the difficulty of gathering information about competitor companies in study, the company which has the biggest market share has been chosen as a competitor for our model company. From now on, this competitor company will be called as Y Company.

Again, a group study has been done while comparing the X Company with Y Company. The questions of "How good are we in satisfying the determined customer requirements and needs?" and "How good is the competitor Y is in satisfying these requirements and needs?" have been asked to 10 people who participate for this research. It has been expected to those who participated in the survey, to answer the questions in a scale of 1 to 5. In this scale, prepared from 1 to 5, 1 means very bad, 2 bad, 3 neutral, 4 good,5 very good.

The benchmarks related to the X and Y Companies given below.

Table 4.11: Matrix Which Shows the Scale Values for Customer Requirements

Customer Requirements	**1**	**2**	**3**	**4**	**5**
Delivery on Time		□	●		
Quality			□●		
The Lowest Cost				□	●
Less Communication			□●		
Service and Guarantee After The Service				□●	
Product Tracing			□	●	
Unproblematic Delivery of The Product				□●	
Insurance of The Product	□		●		
Door-to-door delivery of the product		●	□		

□ X company

● Y Company.

In order to calculate the values in scale given by each person in the practice as one value, each value's arithmetic average has been calculated. There is the planning

matrix formed for X company in the Table below. The results of the group studies can be seen in the “X company” column and “Y company” column.

There are scale points related to how company wants to see itself in the “Target of Firm” column. While determining the “Target of Firm” the views of the company authorities and experts have been taken into consideration by explaining the results of the group study related to how the company is perceived by customers, to the company authorities. Target values have been determined in the X Company to reach a better place in the view of customer by using the facilities available.

Table 4.12: Competition Analysis Matrix for Customer Requirements (PlanningMatrix)

Customer Requirements	Importance Degree	X Company	Y Company	Target of Firm	Progress Ratio	Sales Point	Importance Point	Percent Importance
Delivery on Time	10	2	3	5	2.5	1.5	37.5	25
Quality	9	3	3	5	1.7	1.5	22.95	16
The Lowest Cost	7	4	5	5	1.25	1.2	10.5	7
Less Communication	3	3	3	3	1	1	3	2
Service And Guarantee After The Service	8	4	4	5	1.25	1.5	15	10
Product Tracing	5	3	4	5	1.7	1.5	12.75	9
Unproblematic Delivery of The Product	9	4	4	5	1.25	1.5	16.88	11
Insurance of The Product	5	1	3	3	3	1.2	18	12
Door-to-door Delivery of The Product	6	3	2	4	1.3	1.5	11.7	8
Total							148.28	100

“Progress ratio” column is found by dividing the “target” column to the column which shows the current state of the company. For example, “Delivery on Time”, Progress ratio for customer requirement, has been calculated as 5/2= 2.5 in our practice.

The “sales point” column in the planning matrix has been determined in the meetings made with company authorities. Because sales point is a concept which shows whether the sales of a product improves or not, because of the improvements in the customer requirements. At the end of the meetings with management, improvements in customer requirements such as “Delivery on Time, Quality, The Lowest Cost, Service and Guarantee after the service, Product Tracing, Unproblematic Delivery of the Product, Insurance of the Product, and Door-to-door delivery of the product” which will also increase the sales of the product too have been indicated.

Importance point column compose of multiplication of importance degree, sales point and Progress ratio points. In our practice, importance degree for customer requirement “Unproblematic Delivery of the Product” have been determined as 9 x 1.25 x 1.5= 16.88. With normalization of the importance degree, the Percent importance column is found. Percent importance column is a value which shows Percent importance each customer requirement in total customer requirement. While forming the planning matrix in which customer requirements the company is falling behind the competitor company has been determined especially. Later, in meetings with the company authorities, whether X Company has enough resources to improve these customer requirements or not has been discussed about. The customer requirements which have enough resources to beat the competitors have been determined by the authorities and demonstrated in the sales point column

4.10.1.5 Forming of the Technical Characteristics

Each customer requirement is required to be expressed as technical characteristics. Technical characteristics are determined in practice by taking expert views into consideration. While determining the technical characteristics, for each customer requirement the question of “Which characteristics do we use to satisfy the “A” customer requirements?” has been asked to the people in the group. It has been tried to determine technical characteristics which can realize all customer requirements and needs in the practice. Technical characteristics which can realize the customer

requirements for “the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices” are as follows:

Table 4.13: Technical Characteristics

Customer Requests	Quality Characteristics
Delivery on time	- Agreement with Foreign supplier done the work on this company - To work with companies that Quick response - Seamless communication with the company - Quality Personnel - Market research - Agreement with Firm - Contract - Online program - Reliable transportation - Uninterrupted execution of Maintenance services
Quality	- To work with companies that Quick response - Quality Personnel - Planned - unplanned inspections - Contract - Reliable transportation - Studies Of creating a team spirit
Low cost	- Agreement with Foreign supplier done the work on this company - Market research
Little communication	- To work with companies that Quick response - Seamless communication with the company - Quality Personnel - Agreement with Firm - Contract - Online program
Service and warranty after Service	- Agreement with Foreign supplier done the work on this company - The Aircraft MRO Company establish Foreign supplier company - To work with companies that Quick response - Seamless communication with the company - Quality Personnel - Market research - Agreement with Firm - Contract - Reliable transportation

Product tracking	- Agreement with Foreign supplier done the work on this company - To work with companies that Quick response - Seamless communication with the company - Quality Personnel - Market research - Agreement with Firm - Contract - Online program - Reliable transportation
The smooth delivery of the product	- Agreement with Foreign supplier done the work on this company - The Aircraft MRO Company establish Foreign supplier company - To work with companies that Quick response - Seamless communication with the company - Quality Personnel - Market research - Agreement with Firm - Contract - Reliable transportation - Only Receiving of suitable packaging cargo
Insuring of the product	- Agreement with Foreign supplier done the work on this company - Quality Personnel - Agreement with Firm - Contract - Reliable transportation
Door to door delivery of the product	- Agreement with Foreign supplier done the work on this company - The Aircraft MRO Company establish Foreign supplier company - To work with companies that Quick response - Seamless communication with the company - Quality Personnel - Agreement with Firm - Contract - Reliable transportation

When the customer requirements and technical characteristics are to be examined, it is seen that different customer requirements can be realized within the same technical characteristics.

Table 4.14: Relationship between Customer Requirements and Technical Characteristics

Customer Requirements	Importance Degree	Making a Agreement With External Supplier and Doing Business Through That Company	The Aircraft MRO Company's Establishing External Supplier Company	Working With Companies Answering Quickly	Unproblematic Communication with The Company	Qualified Employee	Planned or Unplanned Controlling	Market Research	Making an Agreement with The Company	Agreement	Online Program	Safe Transportation
Delivery on Time	10											
Quality	9											
The Lowest Cost	7											
Less Communication	3											
Service And Guarantee After The Service	8											
Product Tracing	5											
Unproblematic Delivery of The Product	9											
Insurance of The Product	5											
Door-to-door Delivery of The Product	6											

The relationship between technical characteristics and customer requirement has been demonstrated in the Table 4.14. Although a number of technical characteristics have been determined for each customer requirement as a result of expert views, in order to simplify the practice we have used the most important technical characteristic .

4.10.1.6 Determining the Relationship between Customer Requirements and Technical Characteristics

The relationship between customer requirements and technical characteristics is determined by experts in practice. The relationships part in the study will help to understand whether technical characteristics include the customer requirements enough or not. The relationship values between customer requirements and technical characteristics have been demonstrated with symbols below.

Θ Strong Relationship, expressed with the number 9

O Moderate Relationship, expressed with the number 3

Δ Weak Relationship, expressed with the number 1

In the Table below, the relationship between customer requirements and technical characteristics is demonstrated.

Table 4.15: Relationship Matrix of Customer Requirements for "The domestic and abroad calibration, repairing and shipping processes of testing and measuring devices"

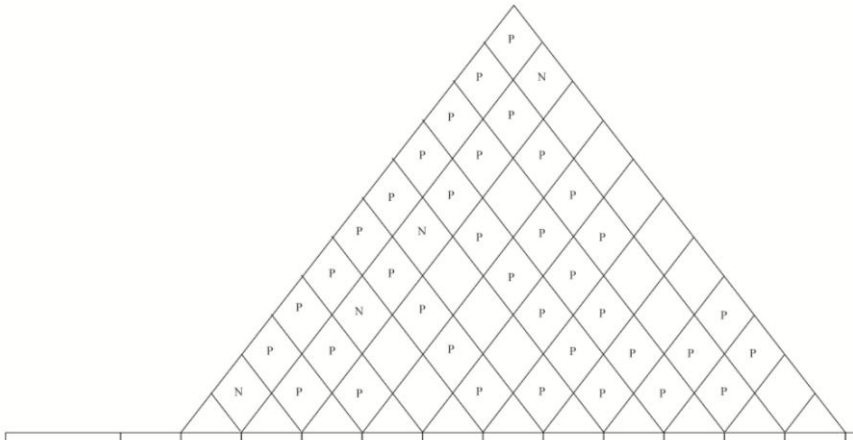
Customer Requirements	Importance Degree	Making a Agreement With External Supplier and Doing Business Through That Company	The Aircraft MRO Company's Establishing External Supplier Company	Working With Companies Answering Quickly	Unproblematic Communication with The Company	Qualified Employee	Planned or Unplanned Controlling	Market Research	Making an Agreement with The Company	Agreement	Online Program	Safe Transportation	Percent Importance
Delivery on Time	10	Θ		Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	25
Quality	9	O	Δ	Θ		Θ	Θ	O	O	Θ	O	Θ	16
The Lowest Cost	7	Θ	O	Δ	O	Δ		Θ	O	O	O	Δ	7
Less Communication	3		O	Θ	Θ	Θ	Δ	O	Θ	Θ	Θ	Δ	2
Service And Guarantee After The Service	8	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	Δ	Θ	10
Product Tracing	5	Θ	Δ	Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	9
Unproblematic Delivery of The Product	9	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	O	Θ	11
Insurance of The Product	5	Θ	O	Δ		Θ	O	O	Θ	Θ		Θ	12
Door-to-door Delivery of The Product	6	Θ	Θ	Θ	Θ	Θ	O	O	Θ	Θ	Δ	Θ	8
Technical Importance Degree	Σ7268	786	349	748	606	844	371	672	762	858	444	828	100
Normalized Technical Importance	100	10.8	4.8	10.3	8.3	11.6	5.1	9.3	10.5	11.8	6.1	11.4	

Lack of enough symbols for relationships or if there is a weaker relationship between the customer requirements and technical characteristics, it is decided that a design for customer requirements and needs cannot be realized. When the relationships part of the Table 4.15 is examined, the multitude of strong relationships show that customer requirements are satisfied enough.

4.10.1.7 Determination of Technical Correlation and Analysis

In this phase the effects of technical characteristics that conflict with one another on the determined customer requirements have been evaluated. As it has been explained in the section, most technical characteristics are related to other technical characteristics. A study which has been made in order to improve one of the determined customer requirements may help another technical characteristics as well as it may affect negatively. For example, if the business is done through that company by making an agreement with External Supplier, The Aircraft MRO Company has to abandon the practice of establishing the External Supplier Company. These relationships have been formed by taking expert opinion into consideration in our study. During our practice, we have faced some problems on assigning the direction of relationship among technical characteristics. The X Company did not give the time and finance for research in order to determine the kind of the relationship.

Table 4.16: Correlation Matrix for Customer Requirements for "The domestic and abroad calibration, repairing and shipping processes of testing and measuring devices"



Customer Requirements	Importance Degree	Making a Agreement With External Supplier and Doing Business Through That Company	The Aircraft MRO Company's Establishing External Supplier Company	Working With Companies Answering Quickly	Unproblematic Communication with The Company	Qualified Employee	Planned or Unplanned Controlling	Market Research	Making an Agreement with The Company	Agreement	Online Program	Safe Transportation	Percent Importance
Delivery on Time	10	Θ		Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	25
Quality	9	O	Δ	Θ		Θ	Θ	O	O	Θ	O	Θ	16
The Lowest Cost	7	Θ	O	Δ	O	Δ		Θ	O	O	O	Δ	7
Less Communication	3		O	Θ	Θ	Θ	Δ	O	Θ	Θ	Θ	Δ	2
Service And Guarantee After The Service	8	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	Δ	Θ	10
Product Tracing	5	Θ	Δ	Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	9
Unproblematic Delivery of The Product	9	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	O	Θ	11
Insurance of The Product	5	Θ	O	Δ		Θ	O	O	Θ	Θ		Θ	12
Door-to-door Delivery of The Product	6	Θ	Θ	Θ	Θ	Θ	O	O	Θ	Θ	Δ	Θ	8
Technical Importance Degree	Σ7268	786	349	748	606	844	371	672	762	858	444	828	100
Normalized Technical Importance	100	10.8	4.8	10.3	8.3	11.6	5.1	9.3	10.5	11.8	6.1	11.4	

4.10.1.8 Technical Benchmarking

In this phase technical characteristics for satisfying the customer requirements have been compared with technical characteristics of the competitor company. In the phase of benchmark of technical characteristics, information from some experienced people and engineers have been taken into consideration. For example, for technical characteristics “To work with companies answering quickly”, a meeting has been set up with the Avionics Component Factory Manager and it learned by working with companies answering quickly and X Company can do some work in 2 hours. This time period is 7 hours in Y Company. X Company has exceeded its target by 1 hour with trusting the working companies answering quickly that the works will be done faster. When the other technical characteristics of X Company compared with the technical characteristics of Y Company the situation has become like this as in the Table 4.17.

Table 4.17: Technical Benchmarking for Customer Requirements for "The domestic and abroad calibration, repairing and shipping processes of testing and measuring devices"

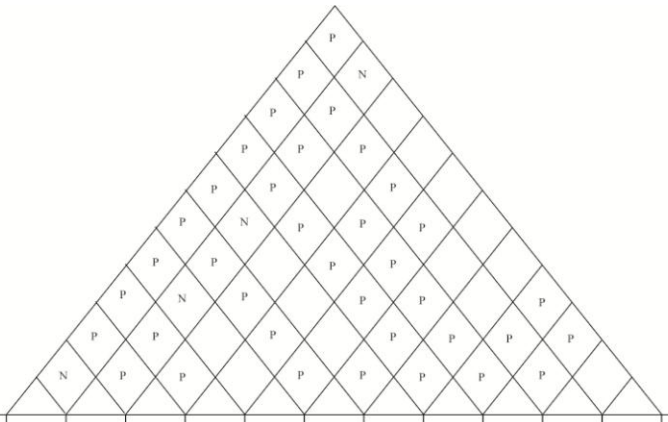
Customer Requirements	Importance Degree	Making a Agreement With External Supplier and Doing Business Through That Company	The Aircraft MRO Company's Establishing External Supplier Company	Working With Companies Answering Quickly	Unproblematic Communication with The Company	Qualified Employee	Planned or Unplanned Controlling	Market Research	Making an Agreement with The Company	Agreement	Online Program	Safe Transportation	Percent Importance
Delivery on Time	10	Θ		Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	25
Quality	9	O	Δ	Θ		Θ	Θ	O	O	Θ	O	Θ	16
The Lowest Cost	7	Θ	O	Δ	O	Δ		Θ	O	O	O	Δ	7
Less Communication	3		O	Θ	Θ	Θ	Δ	O	Θ	Θ	Θ	Δ	2
Service And Guarantee After The Service	8	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	Δ	Θ	10
Product Tracing	5	Θ	Δ	Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	9
Unproblematic Delivery of The Product	9	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	O	Θ	11
Insurance of The Product	5	Θ	O	Δ		Θ	O	O	Θ	Θ		Θ	12
Door-to-door Delivery of The Product	6	Θ	Θ	Θ	Θ	Θ	O	O	Θ	Θ	Δ	Θ	8
Technical Importance Degree	Σ7268	786	349	748	606	844	371	672	762	858	444	828	100
Normalized Technical Importance	100	10.8	4.8	10.3	8.3	11.6	5.1	9.3	10.5	11.8	6.1	11.4	
Measuring Unit		Day	Day	Hour	Hour	Minute	Year	Year	Year	Year	Minute	Day	
The Aircraft MRO Company (Today)		40	30	2	2	10	2	1	1	1		3	
Y Company		40	25	7	4	12	1	1	1	1		7	
The Aircraft MRO Company (Target)		30	25	1	1	5	1	1	1	1		1	

If the table 4.17 is examined, in the case of reducing the target values in technical characteristics such as “Making an agreement with external supplier and doing business through that company, The Aircraft MRO Company’s establishing external supplier company, Working with companies answering quickly, Unproblematic communication with the Company, Qualified employee, Planned or unplanned controlling, Safe Transportation”, the X Company will be able to compete better with other competitors.

4.10.2 Planning the Improvement Project Based on Results

At the end of all this phases, a final house of quality has been formed like in the Table 4.18. As a result of the study, the prior customer requirement is “Delivery on Time”. Because it is the customer requirement that has the most Importance Point and can compete as a Sales point. That’s why, in order to improve the quality and satisfying the customer requirements, attention must be given to this customer requirement. Before It has been determined before by the expert opinions that the Company can satisfy “Delivery on Time” customer requirement with technical characteristics such as “Making an agreement with external supplier and doing business through that company, Working with companies answering quickly, Unproblematic communication with the Company, Qualified employee, Planned or unplanned controlling, Market research, Making an agreement with the company, Agreement, Online program, Safe Transportation”. If the technical importance degrees of these technical characteristics are examined, it can be said that the characteristics of “Agreement, Qualified employee, and Safe Transportation” are characteristics that can give advantages to company in this competition against Y Company. Briefly, if the X Company can satisfy the customer requirement “Delivery on Time” by improving “Delivery on Time” and technical characteristic of “Agreement, Qualified Employee, Safe Transportation”, it can improve the quality and can have the competition advantage in the market.

Table 4.18: House of Quality for Customer Requirements for "The domestic and abroad calibration, repairing and shipping processes of testing and measuring devices"



Customer Requirements	Importance Degree	Making a Agreement With External Supplier and Doing Business Through That Company	The Aircraft MRO Company's Establishing External Supplier Company	Working With Companies Answering Quickly	Unproblematic Communication with The Company	Qualified Employee	Planned or Unplanned Controlling	Market Research	Making an Agreement with The Company	Agreement	Online Program	Safe Transportation	X Company	Y Company	Target of Firm	Progress Ratio	Sales Point	Importance Point	Percent Importance
Delivery on Time	10	Θ		Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	2	3	5	2.5	1.5	37.5	25
Quality	9	O	Δ	Θ		Θ	Θ	O	O	Θ	O	Θ	3	3	5	1.7	1.5	22.95	16
The Lowest Cost	7	Θ	O	Δ	O	Δ		Θ	O	O	O	Δ	4	5	5	1.25	1.2	10.5	7
Less Communication	3		O	Θ	Θ	Θ	Δ	O	Θ	Θ	Θ	Δ	3	3	3	1	1	3	2
Service And Guarantee After The Service	8	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	Δ	Θ	4	4	5	1.25	1.5	15	10
Product Tracing	5	Θ	Δ	Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	3	4	5	1.7	1.5	12.75	9
Unproblematic Delivery of The Product	9	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	O	Θ	4	4	5	1.25	1.5	16.88	11
Insurance of The Product	5	Θ	O	Δ		Θ	O	O	Θ	Θ		Θ	1	3	3	3	1.2	18	12
Door-to-door Delivery of The Product	6	Θ	Θ	Θ	Θ	Θ	O	O	Θ	Θ	Δ	Θ	3	2	4	1.3	1.5	11.7	8
Technical Importance Degree	Σ7268	786	349	748	606	844	371	672	762	858	444	828						148.28	100
Normalized Technical Importance	100	10.8	4.8	10.3	8.3	11.6	5.1	9.3	10.5	11.8	6.1	11.4							
Measuring Unit		Day	Day	Hour	Hour	Minute	Year	Year	Year	Year	Minute	Day							
The Aircraft MRO Company (Today)		40	30	2	2	10	2	1	1	1		3							
Y Company		40	25	7	4	12	1	1	1	1		7							
The Aircraft MRO Company (Target)		30	25	1	1	5	1	1	1	1		1							

4.10.3 Suggestions Related to QFD

Good communication between units affects the success of QFD matrix. The main factor in the success of the company is the unity of workers' effort in reaching the same target. Therefore, QFD matrix offers companies a new point of view that supports group work.

QFD is quality equipment which helps companies to gain the competitive advantage. Because, companies are under the pressure of conscious customers who know what they want .This pressure leaves the companies in the necessity of fast and true determining the customer requirements. Because of this, the companies that want to be successful have to be close with their customers, analyze them and adapt new changes quickly. Moreover, because the companies with QFD management can see their competitors' situation in the market, they can also evaluate opportunities and advantages available. This situation gains the company the competitive advantage. Consequently; active companies because of financial difficulties seek for short-time financial solutions. On the contrary, the process of QFD offers long term success, customer satisfaction, providing continuity, reducing the cost and increasing the production volume.

4.10.4 Result and Evaluation

Final version of the house of quality which is formed as a result of explained phases has been offered in the Table 4.18. If the importance degree column of House of Quality is examined, it can be understood that the prior requirement to take customers to service offering phase is "Delivery on Time". If the technical characteristics for offering "Delivery on time" are examined, it is understood that 10 of a total 11 technical characteristics are related to it. Among these qualities, "Making an agreement with external supplier and doing business through that company, working with companies answering quickly, unproblematic communication with the company, Qualified Employee, Planned or unplanned controlling, Market Research, Making an agreement with the company, Agreement, Online Program, Safe Transportation" are the most important ones to satisfy this requirement ,and any improvement in these, will gain The Aircraft MRO Company a serious competition advantage by increasing the satisfaction that is expected from this critical requirement. When the benchmark values are

examined with the Y Company especially, it can be seen that, there is no big difference (The Aircraft MRO Company (X Company) = 2, Y Company = 3) between the companies, also considering the final point is "5", there is a big field open to improvement related to this factor. Finally, it can be said that Aircraft MRO Company's focusing on Delivery on Time is of great importance.

The second factor that follows "Delivery on Time" is "Quality" with 22.95 Importance Point. But, although this factor is important, there isn't a superiority of The Aircraft MRO Company (X Company) to its competitor Y Company (The Aircraft MRO Company (X Company)= 3, Y Company= 3) So, we can say that the Aircraft MRO Company's (X Company) following this , by improving is important too.

"Insurance of the product" follows the "Quality" factor. The technical characteristics that affect this factor coincide with "Delivery on Time" factor. In other words, any improvement on "Delivery on Time" factor will contribute to the improvement of the "Insurance of the product" too. In other words, improvements on these two factors can be managed to together.

In addition to these, when the first three results are evaluated it is understood that "Delivery on Time" and "Quality" are the most important factors for Aircraft MRO Company. In order to be successful Aircraft MRO Company should focus on those two.

In terms of importance degrees, the following factors are "Unproblematic delivery of the product", "Product Tracing", "Door-to-door delivery of the product." Aircraft MRO Company defines "Making an agreement with the external supplier and doing business through that company", "The Aircraft MRO Company's establishing external supplier company", "Working with companies answering quickly", "Unproblematic communication with the company", "Qualified employee", "Planned or unplanned controlling", "Market research", "Making an agreement with the company ","Agreement"," Online program" "Safe Transportation" as principal characteristics in "Unproblematic Delivery of the Product" basic characteristics. .It can be said that, The Aircraft MRO Company is successful in "Unproblematic Delivery of the Product" and it would be right to continue its current strategy.

“Product Tracing” is principally a factor that makes “Making an agreement with the external supplier and doing business through that company”, “The Aircraft MRO Company’s establishing external supplier company”, “Working with companies answering quickly”, “Unproblematic communication with the company”, “Qualified Employee”, “Planned or unplanned controlling”,” Market Research”, “Making an agreement with the company “,“Agreement”, “Online Program“, “Safe Transportation” necessary. When those characteristics are evaluated as a whole, it can be seen that nearly all of them are investments that require a long term to see their results. The Aircraft MRO Company’s current policies are seen appropriate but most of all, it can be said that an investment to Online Program is of great importance for the continuity of the competition in this critical factor. Principally, it can be understood that focusing on this Online Program and getting its quick results can give the Aircraft MRO Company, with little cost, a great competitive advantage.

The point (3) gotten from the factor of “Door-to-door delivery of the product”, is higher than the point of Y Company on the same factor and when considered that the highest point is “5”, it is seen that the field is highly open to improvement.

It can be said that it is appropriate to maintain the current state of the factor “Service and Guarantee after the service” and determine strategy according to the competitor company’s improvement in the factor by tracking the competitor’s state constantly.

The Aircraft MRO Company’s point in the “The Lowest Cost” factor is lower than the Y Company’s point in the same factor. But this is not a situation for the moment to worry but of process tracking the competitor’s state should be done continuously.

Surprisingly Less Communication is the least factor to be considered. On the other hand, The Aircraft MRO Company’s point in that factor is equal to the point of Y Company in the same factor and that shows there isn’t a situation to worry.

When the technical characteristics used for satisfying the technique customer requirements are examined comparatively, it is seen that “Agreement” is the most important of all. It is followed by “Qualified Employee” and “Safe Transportation”, in

the third degree there are “Making an agreement with external supplier and doing business through that company”, “ Making an agreement with the company”, “Working with companies answering quickly”, in the forth degree “Market Research”, “Unproblematic communication with the company”, “Online Program” is in the fifth and “The Aircraft MRO Company’s establishing external supplier company”, “Planned or unplanned controlling” are the most important of the sixth degree. Thus, in future improvements, these priorities have to be taken into consideration, it can be said that, this will help the optimum usage of the resources.

CHAPTER 5

RESULTS AND CONCLUSION

We live in a world which changes constantly and increases its speed of change. This change forces the companies to comply with it and to make innovations consistently; on the other hand it confronts them with an intensive competition. Because of this increasing competition the organizations deal with the subjects of efficiency, productivity, quality, producing low costs products, satisfying of expectations for a short delivery time as well as following the technological developments in order to survive and to continue their lives in market. As a result of this situation, the purpose of the organizations is to reduce the operational costs and waste.

In this study the Value Stream Mapping (VSM) and Quality Function Deployment (QFD) concepts have been applied in Maintenance, Repair and Overhaul (MRO) Company, which operates in aviation sector, outside of production sector. The aim of this study is to show that VSM and QFD methods can be used for increasing productivity in an MRO company. The cause of aviation sector choice as a work field is not encountering with a study of VSM and QFD, which have been done in this sector, during the survey of literature. So this study has been done so that it can contribute for this sector and guide for the future studies.

As a first step, “the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices” of the current state has been mapped out by Value Stream Mapping (VSM) and the wastes of the process found. Then, the process has been improved by the lean principles and a future state map drawn by VSM method. The results of this study display that VSM helped us to see the wastes and bottleneck in the period of the “domestic and abroad calibration, repairing and shipping processes of testing and measuring devices”

This workshop has been established in order to examine the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices, to find the units where delays are happening in this process and to improve this process for at least %10 by working between the calibration factory and the other units. In this practice, the bottlenecks related to this process are, company's working with other companies and facing difficulties in logistic process except America. Workers' requirements from the company related to the process are the formations of a fast work flow by working with only one vendor.

In the new state, the supplier process has been removed, while Lead time is 23 days in domestic excluding the supplier, in the future state it is reduced to 1 hour, and abroad Lead Time reduced to 27 hours from 27 days excluding the supplier. We exclude the supplier because we don't know in how much time the company that works for us does the transactions. 23 days pass during the output of the device from the calibration factory and it's delivery to the customer. After the device arrives to the calibration factory, it passes to the company. If "urgent" is not written on the devices, 23 passed days are the time periods for circulation of the documents only. When the device arrives to the calibration factory, the TAT period (average waiting period after arriving to the calibration factory) starts. The device is sent to the Eskişehir, and except the repair period in Eskişehir, 23 days passes only. The device arrives to the calibration factory and it has been sent for calibration to the company, later received by the factory when it comes back to the Calibration factory, this period takes for 15 days.

In order to reach Lead Time abroad, it has been decided to do studies, researches in the beginning of the year, prepare the list, agreements to be done between the units and prepare declarations for calibration. Because the agreements and the studies will take some time, the results of this workshop, in other words, the data will be accessible in 6 months after studies and agreements required for the future state have been done.

As a second step, "House of Quality " has been used for translating the customers' requests to the technical characteristic in the period of, "the domestic and abroad calibration, repairing and shipping processes of testing and measuring devices" by Quality Function Deployment (QFD).

If the importance degree column of House of Quality is examined, it is understood that the prior requirement to take customers to service offering phase is “Delivery on Time”. The second factor that follows “Delivery on Time” is “Quality” with 22.95 Importance Point. “Insurance of the product” follows the “Quality” factor.

Also, when the first three results are evaluated it is understood that “Delivery on Time” and “Quality” are most important factors for Aircraft MRO Company. In order to be successful Aircraft MRO Company should focus on those two.

In terms of importance degrees, the followings factors are “Unproblematic delivery of the product”, “Product Tracing”, “Door-to-door delivery of the product”, “Service and Guarantee after the service”, “The Lowest Cost”, “Less Communication”. Surprisingly, “Less Communication “is the least factor to be considered.

When the technical characteristics used for satisfying the technique customer requirements are examined comparatively, it is seen that “Agreement” is the most important of all. It has been followed by “Qualified Employee” and “Safe Transportation”. In the third degree there are “Making a agreement with external supplier and doing business through that company”, “ Making an agreement with the company”, “Working with companies answering quickly”, and in the forth degree there are “Market Research”, and “Unproblematic communication with the company”. “Online Program” is in the fifth and “The Aircraft MRO Company’s establishing the external supplier company”, “Planned or unplanned controlling” are the most important of the sixth degree. Thus, in the future improvements, these priorities have to be taken into consideration, it can be said that, this will help the optimum usage of the resources.

As a result of VSM and QFD’s application, a lot of beneficial data for the company have been gained. During the study, it has been seen that there are a lot of factors, which are effective for application of VSM and QFD. The most important one of these factors is that top management should comprehend the methods of VSM and QFD and support this project. The obtained data from the study should be applied so that the intended results can be obtained for VSM and QFD application. The obtained data with the study, done in a company in aviation sector has been served to the

management the company and it is management's decision whether the data will be applied or not.

VSM and QFD are run by a team, which consists of members from different functions of company. It will provide positive developments on culture of the company by increasing the communication in company. Accuracy of communication between the sections affects directly the success of VSM and QFD. Thus, VSM and QFD serve to the companies a new viewpoint which supports the teamwork. Unless the top management interests in VSM and QFM, it will reduce effects of teamwork and will affect negatively the motivation of the team members.

Another subject, what is important for success of VSM and QFD applications, is about education. During the study, VSM and QFD have been introduced to the team members but it is not enough. Organization of seminar about VSM and QFD is necessary for the team members. Training seminars about VSM, QFD and other quality techniques should be provided and an application of these methods by the companies can be generalized in the country. VSM and QFD methodology, which aims to provide high customers satisfaction by using optimal the sources of company, has been introduced recently in our country with the benefits of symposiums about this subject.

Reducing of total costs in company and increasing of productivity can be provided by application of VSM and QFD methods. At the same time the companies can know the situations of their competitors in the market with VSM and QFD methods and benefit from the opportunities and advantages. This situation provides superiority in the competition.

Consequently, operating companies want to find financial solutions in the short run because of their financial difficulties. However, VSM and QFD applications are easy and cheap but they need time and provide radical changes slowly. At the same time, the benefits of VSM and QFD are being successful in the long run, customers' satisfactions and providing their continuity, reducing of costs and increasing of the production volume. Using these methods will provide advantages of competition in international markets for Turkish companies.

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