THE APPLICATION OF LEAN MANUFACTURING PRINCIPLES TO AN AIRCRAFT MAINTENANCE, REPAIR AND OVERHAUL (MRO) COMPANY

by

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ABSTRACT

THE APPLICATION OF LEAN MANUFACTURING PRINCIPLES TO AN AIRCRAFT MAINTENANCE, REPAIR AND OVERHAUL (MRO) COMPANY

This study addresses the application of lean manufacturing concepts to a non-manufacturing environment – a maintenance, repair and overhaul (MRO) company. The goal of this study is to investigate how lean manufacturing tools can be adapted for MRO work environment to identify and eliminate waste so that financial performance, productivity, quality, safety and health are improved. The study attempts to implement some of the lean techniques to an MRO company analogous to a manufacturing work environment. The idea is tested on MRO Company of Turkish Technic. First of all, value stream mapping (VSM) is used to map the current state for the C-Check maintenance package process and then used to improve the process using lean principles and map its future state. Then, 5S is used in stands and ladders area, main tool shop and seat shop to organize these worksites and eliminate unnecessary movements, and non-value-adding search, and select therbligs as well as improve safety and ergonomics issues in these work areas. Lastly, accelerated improvement workshop (AIW) is used as the tool to improve the assembly process of HPC Forward and HPT Shroud / LPT Nozzle modules of an aircraft engine. Results of the study showed that VSM indicated the waste and bottleneck areas in the C-Check package process. It also provided an implementation plan, which reduced the lead time of a package from 12 days to 2½ days. In addition, 5S provided an efficient and organized workplace and eliminated safety and ergonomics problems related with the work area. Finally, AIWs helped to increase efficiency significantly for three module assembly processes. All these improvements showed that lean manufacturing methods can be applied in an MRO company in order to increase productivity by eliminating waste.

ÖZET

YALIN ÜRETİM TEKNİKLERİNİN BİR UÇAK BAKIM, TAMİR VE REVİZYON ŞİRKETİNDE UYGULANMASI

Bu çalışma yalın üretim kavramlarının üretim dışındaki bir ortamda, bir bakım, tamir ve revizyon (BTR) şirketinde, uygulanması konusunu incelemektedir. Bu çalışmanın amacı yalın üretim araçlarının, israfı tespit ederek ortadan kaldırmak suretiyle finansal performans, verimlilik, kalite, iş güvenliği ve iş sağlığı konularında iyileştirmeler sağlaması için, bir BTR ortamına nasıl uyarlanabileceğini araştırmaktır. Bu çalışmada bazı yalın üretim teknikleri, imalat ortamındakine paralel bir şekilde bir BTR şirketine uygulanmaya çalışıldı. Bu fikir bir BTR şirketi olan Türk Hava Yolları (THY) Teknik'te denendi. İlk adım olarak, Değer Akışı Haritalama (DAH) yöntemi kullanılarak C-Bakım paketi sürecinin mevcut durum haritası çıkarıldı ve süreç içindeki israflar tespit edildi. Bundan sonra, yalın prensipleri kullanılarak süreç iyileştirildi ve tekrar DAH yöntemi ile gelecek durum haritası çizildi. Daha sonra, çalışma alanlarını düzenlemek, gereksiz hareketleri ve değer katmayan aramaları ortadan kaldırmak, çalışma yöntemini belirlemek ve bu alanlardaki iş güvenliği ve ergonomi koşullarını iyileştirmek amacıyla sehpa ve merdiven alanında, ana alet atölyesinde ve koltuk atölyesinde 5S yöntemi kullanıldı. Son olarak, bir motorun HPC Forward ve HPT Shroud / LPT Nozzle birimlerinin montaj süreçlerini iyileştirmek için Hızlandırılmış Geliştirme Çalışması (HGÇ) yöntemi kullanıldı. Çalışmanın sonuçları gösterdi ki, DAH, C-Bakım paketi sürecindeki israfları ve darboğazları görmemize yardımcı oldu. Aynı zamanda bize, süreci 12 günden 2½ güne indirecek bir uygulama planı sağladı. Ayrıca, 5S verimli ve düzenli bir çalışma alanı sağladı ve çalışma alanıyla ilgili güvenlik ve ergonomi sorunlarını giderdi. Son olarak, HGÇler üç motor biriminin montaj süreçleri için önemli verimlilik artışı sağladı. Tüm bu iyileştirmeler gösterdi ki, yalın üretim yöntemleri, bir bakım, tamir ve revizyon şirketinde verimliliği artırmak için uygulanabilir.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AGB	Accessory Gear Box
AIW	Accelerated Improvement Workshop
AMM	Aircraft Maintenance Manual
APU	Auxiliary Power Unit
BOM	Bill of Materials
C.O.	Change Over
C.T.	Cycle Time
DAH	Değer Akışı Haritalama
DGCA	Directorate General of Civil Aviation
DOT	Department of Transportation
EASA	European Aviation Safety Agency
ECD	Expected Completion Date
EGT	Exhaust Gas Temperature
FAA	Federal Aviation Administration
FOD	Foreign Object Damage
HİÇ	Hızlandırılmış İyileştirme Çalışması
HPC	High Pressure Combustor
HPT	High Pressure Turbine
HR	Human Resources
HVC	Hardware Variability Control
IT	Information Technologies
JAA	Joint Aviation Authorities
KPI	Key Performance Indicator
LPT	Low Pressure Turbine
L.T.	Lead Time
MLG	Main Landing Gear
MRO	Maintenance, Repair and Overhaul
NDT	Non-Destructive Testing
OEM	Original Equipment Manufacturers
OHSAS	Occupational Health and Safety Assessment Series

PPC	Production Planning and Control
QEC	Quick Engine Change
SPC	Statistical Process Control
SWCS	Standard Work Combination Sheet
TAMES	Turkish Airlines Maintenance, Engineering and Inventory System
TAT	Turn Around Time
TDS	Technical Documentation System
THY	Türk Hava Yolları
U.T.	Up Time
VR	Variability Reduction
VSM	Value Stream Mapping
WCS	Work Card System
WIP	Work in Process
W/O	Work Order
W/S	Work Scope

1. INTRODUCTION

1.1. Background

This study addresses the application of some of lean manufacturing concepts to a non-manufacturing industry – a maintenance, repair and overhaul (MRO) company. Lean manufacturing, also known as Toyota production system, is a superior way of production that aims to eliminate all waste in the processes of a company and achieve a continuous value flow to the customer. Waste (muda in Japanese) is defined as every activity that does not add value to the final product and/or service, from the customer's viewpoint. Lean manufacturing was created and developed by Toyota company after the Second World War and became widespread especially in the automotive industry after the oil crisis in 1973. Although there are a lot of applications and research in the automotive industry, companies in other industries have recently been discovering the competitive power of lean manufacturing. The primary objective of lean manufacturing is to help manufacturers who have a desire to improve the company's operations and become more competitive through the implementation of various lean manufacturing tools and methods.

Lean is to manufacture only what is needed by the customer, when it is needed and in the quantities ordered. The manufacture of goods is done in a way that minimizes the time taken to deliver finished goods, the amount of labor required, and the floor-space required, and it is done with the highest quality, and usually, at the lowest cost.

1.2. Problem Statement

Almost any kind of process, whether it is a manufacturing, service or MRO process, potentially has waste that can be eliminated by lean methodology. Companies implementing lean believe that if there is a waste in a process, it can be improved by lean approach. In lean terms, "waste" means every activity in a process that does not add value for the customer, whether internal or external.

Lean methodology has been applied widely in manufacturing industry such as automotive, electronic and appliance manufacturing. On the other hand, its application to other sectors, especially to an MRO company is relatively new and rare. Since an MRO work environment is quite different than manufacturing work environment, one may hypothesize that the implementation procedures of lean concepts and outcome measures will show some differences. While it seems that some of the lean tools are difficult to adapt in an MRO work environment, others are not. For example, just-in-time may be easily implemented for routine maintenance jobs, but it may be difficult to implement for a repair work, since it will be difficult to standardize repair jobs due to the nature of work. On the other hand, value stream mapping and 5S tools can be applied to an MRO work environment the same way it is applied to a manufacturing work environment. In order to compete in today's competitive global market, along with manufacturing side of a business, MRO side of the business is also need to gain a competitive advantage. Lean philosophy is one of the ways that may assist to gain this competitive edge.

1.3. Study Objectives

The goal of this study is to investigate how some of the lean tools can be adapted for an MRO work environment and to evaluate their benefits. This study hypothesize that there are big opportunities for improvements in MRO companies if lean tools are implemented properly.

The objective therefore is to demonstrate how lean manufacturing tools when used appropriately can help the MRO industry eliminate waste, improve productivity, financial performance, quality, safety and health.

In this study, the work will be conducted in Turkish Technic, which used to be the maintenance function of Turkish Airlines before separating in May 2006 as a profit center. Just before the separation, Turkish Airlines signed a consultancy agreement with Boeing in order to spread lean philosophy throughout the company and become a lean MRO center. The author of this study has been working for Turkish Airlines and Turkish Technic since

December 2004 as a process improvement engineer and worked as the team leader or co-leader in the workshops presented in this study.

2. KEY CONCEPTS AND LITERATURE REVIEW

The aim of this section is to give solid background information about lean manufacturing. In section 2.1, birth and rise of mass production, its advantages over craft production and reasons that mass production fell behind in the global competition, especially after the oil crisis in 1973, will be explained. Then, in section 2.2, birth and rise of lean organizations and their advantages over mass production organizations will be summarized. The fundamental book "The Machine That Changed the World" by Womack, Jones, and Roos (1991) will be used as a reference in these sections.

In section 2.3, five pillars of lean philosophy will be introduced using another fundamental book as a reference, "Lean Thinking" by Womack and Jones (2003). These five pillars are value, value stream, flow, pull and perfection.

In section 2.4, seven important process improvement methods of lean manufacturing will be explained. These are takt time, continuous flow, supermarkets, pacemaker process, production leveling, pulse and every piece every methods. "Learning to See" by Rother and Shook (1999) will be the main reference book for this section.

Then, in section 2.5, Toyota's 14 business principles will be summarized using the fundamental book "Toyota Way" by Liker (2004). These 14 principles can be grouped into four categories. These are long term philosophy, principles related with the process, principles related with the employees and partners, and problem solving culture.

2.1. Mass Production

Before Henry Ford's 1908 Model T, craft production was the common method among car manufacturers. This method needed highly skilled work force, who understand every aspect of car manufacturing. Design of parts and components mostly came from suppliers and a central entrepreneur was coordinating customers, suppliers and production. Workers were using general purpose machines. Also, production volume was very low and customers were from higher classes of the society, who want customized cars unique to themselves. So, no two cars were exactly the same because of different designs and variations in the processes.

In 1908, Henry Ford designed Model T, which became the milestone for automotive industry. This car was important for two aspects: It was produced in a moving assembly line and it was very easy to drive and repair. But, according to Womack *et al.* (1991), these innovations were not the most important ones:

> *"The key to mass production wasn't – as many people then and now believe – the moving, or continuous, assembly line. Rather it was the complete and consistent interchangeability of parts and the simplicity of attaching them to each other. These were the manufacturing innovations that made the assembly line possible."*

Table 2.1 shows efficiency gained by converting from craft production to mass production (Womack *et al*., 1991).

Workers had a very limited task in mass production when compared to craft production. In the latter, a skilled craftsman was performing almost every task to complete a car and the cycle of his task was very long. On the other hand, a mass production worker had a very limited task, for example assembling one door of the car, repeated over and over during his shift. He did not have to know what the other workers were doing. "As a result, the workers on the line were as replaceable as the parts on the car." (Womack *et al*., 1991)

Table 2.1. Craft production vs. mass production

Minutes of Effort to Assemble:	***Late Craft Production, Fall 1913***	***Mass Production, Spring 1914***	***Percent Reduction in Effort***
Engine	594	226	62
Magneto	20	5	75
Axle	150	26,5	83
Major Components into a Complete Vehicle	750	93	88

By using mass production techniques, Ford produced 2.1 million Model T chassis in 1923, which is the success proof of standardized mass production (Womack *et al*., 1991). 1955 was maybe the golden year of mass production. Ford, General Motors and Chrysler sold 95 per cent of all cars in the US and six models made up 80 per cent of all sales (Womack *et al*., 1991).

The diffusion of mass production into the Europe was rather slow. Strong craft production practices, economic chaos and the Second World War were the major causes of this slow diffusion. Only after 1950, most of the European car manufacturers converted to mass production. It was almost 30 years after Henry Ford's model T (Womack *et al*., 1991).

After 1973 oil crisis, the power of mass production started to diminish both in the US and Europe. Firstly, repeating a small task over and over again during one shift started to become unbearable for mass production workers and especially in Europe, workers demanded spending fewer hours in the factory. Secondly, economies of scale was forcing producers to work in huge batches, which meant lots of work in progress and finished goods inventory whereas customers were then demanding higher variety of products in higher quality and in shorter time. Huge batches and unmotivated workers were causing too many quality problems and these problems were being detected very late in the process. Actually, quality was the responsibility of end-of-line inspectors who were removing defective products for rework. Thirdly, engineers were also specialized in narrower branches, which was weakening communication between them and in turn, creating design problems and increasing time to market for new products (Womack *et al*., 1991). It was just such an environment when a totally new production system was born and developing in Japan and it was going to change the way of doing business radically.

2.2. Lean Production

Womack *et al*. think that lean production is a prevailing way of production which makes it possible to produce higher quality products in a wider variety, using fewer resources (1991).

Lean production, also known as Toyota production system, was born in Japan. The founder Toyoda family used to produce textile machines in the late 19th century and military trucks in the late 1930s. After the Second World War, they decided to produce commercial cars and trucks, but they had some very big problems to overcome, in order to compete in the global market (Womack *et al*., 1991):

- They had a very limited domestic market in Japan, who wanted a wide variety of cars and trucks.
- Workers and unions were very strong in Japan and there were no immigrants or inexpensive work force.
- After the war, there was not enough capital in Japan to buy technology and start production.
- Outside producers were very eager to start production in Japan.

2.2.1. Dye Changes

Japan government prohibited direct foreign investments in motor vehicle industry, which was a temporary solution to the last problem, but was not enough for global competition. Taiichi Ohno, Toyota chief production engineer, noticed that they need a different method than mass and craft production systems in order to overcome these problems. He first concentrated on dye changes. Mass producers were using dye change specialists in order to avoid quality problems. Dyes used to be changed every two to three months and it used to take one day on average to change a typical dye. Ohno's idea was to make dye changes easier and shorter, so that workers would not wait idle and it would be possible to produce smaller batches and change dies more frequently. By using simple adjustments and rollers to move the dyes in and out and after thousands of tries, Ohno was able to reduce the time needed to change a typical dye from one day to only three minutes. Reducing the time necessary for dye change gave three advantages to Toyota over mass producers: First of all, working in small batches reduced the cash and space needed for huge inventories. Also, if a problem occurs in the process, it would not repeat in a big batch and could be noticed earlier. Moreover, there were no need for dye change specialists and workers would not wait idle for one day. On the other hand, in order for these changes to work, Ohno needed high quality and highly motivated workers (Womack *et al*., 1991).

2.2.2. Crisis and Work Teams

In the late 1940s, Toyota experienced a crisis and had to lay out one fourth of its work force. Also, Kiichiro Toyoda took the responsibility of the crisis and resigned from the company. Remaining workers got two guarantees: Firstly, they would have a lifetime work in Toyota and secondly, they would be paid according to their seniority in the company and also the company's overall profitability (Womack *et al*., 1991).

Ohno carried on his works in the factory by creating small teams and assigning leaders to them, which were different from the foremen in mass production systems. Foreman did not do any assembly task and his responsibility was to make sure that assembly workers comply with the rules. On the other hand, team leader would do assembly tasks, coordinate the team and do the work of any absent worker (Womack *et al*., 1991).

2.2.3. Quality and Rework

Mass producers concentrated on two things: Output and out-the-door quality. Thus, stopping the line in order to fix a problem was not a good idea in a mass production facility, since it meant spending extra hours to meet the quota. Instead, there were big rework areas in the factory, where defective finished products were being rectified before being delivered to the customer (Womack *et al*., 1991).

From Ohno's point of view, this was a huge waste, since nobody other than the assembly worker was in fact adding value to the product. So, he decided to give some additional tasks to the assembly workers, such as cleaning and maintenance of their machines and work area, minor repairs and quality checking. Thus, there was no need for other specialists who did not add value to the product. Also, he wanted from teams to periodically allow time and think about better ways of doing their tasks, which he called *Kaizen* activities. Moreover, in order to eliminate rework activities, he gave each team the authority to stop the line if a problem occurs. At first, the line stopped over and over again. This was very discouraging for everybody. In order to find the root causes of the problems and solving them permanently, Ohno wanted everybody to ask "Why?" at least five times when a problem occurred. Finally, they got an assembly line, which almost never stops and produces the best quality products for the customer (Womack *et al*., 1991).

2.2.4. Supply Chain

Ohno also saw the problems related with the supply chain model of the mass producers. Suppliers did not have any opportunity or motivation to improve the designs of their products and they were like the assembly workers who did the work given and nothing more. Also, changing suppliers frequently based on the lowest price was preventing information sharing among each party. Moreover, demand of the assembler firm was varying significantly in time and orders were given in very short notice to the supplier, which was causing very large finished product inventory cost for the suppliers (Womack *et al*., 1991).

Toyota's approach to the supply chain was to include first tier suppliers in product development process and let them develop a full system which would work in accord with the others. They were given performance specifications, dimensions, weight and the target cost to develop such a system and Toyota did not decide on the details of the design, since it was the engineering decision of the supplier firm. Moreover, Toyota supported its suppliers to improve their processes and sometimes provided loans to buy new equipment or machinery (Womack *et al*., 1991).

One last and maybe the most important idea of Ohno about coordinating the flow of parts inside the factory and also between the supplier firms and Toyota was the *Kanban* system, which in fact nothing more than containers or cards. However, the power of kanban came from using these containers and cards as production signals for the previous process. Thus, no single process would produce unnecessary products unless a demand came from the next process, which meant eliminating all inventories in the system. It was certainly a very risky method, since a small problem might stop the whole system. It necessitated detecting problems before occurring and creating preventive solutions for them. After years of efforts, Toyota succeeded in creating a just-in-time system, which has the minimum inventory, highest productivity and product quality (Womack *et al*., 1991).

2.2.5. Product Development

Mass production companies approached product development by dividing engineering into very specialized segments, which inherently created coordination problems. They formed product development teams from specialists from different areas and assigned a team leader who had limited authority. Each member of the team reported to his/her own manager instead of the team leader. Toyota on the other hand, formed teams with very strong leaders, who had specialty in all necessary subjects. They provided the team leader with more authority relative to his/her responsibility. That was unusual for a mass production company, in which authority is limited with the responsibility. Also, they encouraged and rewarded strong team players rather than those successful only in their own areas. As a result, Toyota has been able to develop a new car spending almost half the time, effort and money necessary for a mass producer (Womack *et al*., 1991).

2.2.6. Dealers and Customers

In the mass production system, in order to level production in the factory, assemblers used dealers as shock absorbers towards changing demand structures. Dealers on the other hand, adjusted prices in order to match the demand with supply and tried to maximize their profits. Thus, everybody in the system was hiding information from each other creating mistrust among each party. Toyota wanted to create a long-term relationship between the factory and the dealers and between the dealers and the customers. In order to eliminate the finished product inventory, Toyota started to implement build-to-order system. This integrated the dealer into the production system, since the order was the first signal for production. Also, Toyota integrated the customers into the product development process by using its customer database and continuously visiting previous buyers and asking them about their choices as their income levels, family sizes or other demographics changed (Womack *et al*., 1991).

2.3. Five Pillars of Lean Philosophy

2.3.1. 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.

Some companies experience product failures even though they have high-tech products with strong technical functions and complex systems. The main reason of these product failures is that their values are defined by the company itself and not by the customers. They are either too expensive for the customers to acquire or they do not exactly match the real needs of the customers. "Providing the wrong good or service the right way is muda (waste)." (Womack and Jones, 2003)

2.3.2. The Value Stream

The second step of lean thinking is to analyze and define the value stream. Value stream includes every stages of creating the value for the customer, whether it is a product, service or both. It also includes the transfers from one company to the other during the value creation and there are almost always huge wastes inside this value stream. It is required to look at the whole supply chain as a value stream in order to create a win-win relationship between companies (Womack and Jones, 2003).

There are three types of activities in a value stream:

i) <u>Value-Added activities</u>: These activities are just what the customer wants. For example, installing the parts in an assembly line or flying a customer from one city to the city s/he wants to go (for example, Samsun-Adana).

ii) <u>Non-Value-Added but Necessary activities</u>: These activities are not what the customer actually wants, but they must be done in current work conditions and can not be eliminated in the short term. For example, filling the necessary forms after installing parts or flying a passenger first to a hub city and then to the city s/he wants to go (for example, Samsun-Ankara-Adana).

iii) Non-Value-Added and Unnecessary activities: These are the activities that do not add value for the customer and can be eliminated in the short term. Every kind of wait, rework, preparation or unnecessary transportation is that kind.

Below are the most common wastes targeted by lean methods, according to Larson and Greenwood (2004):

- Manufacturing wastes
  - Inventory
  - Defects
  - Overproduction
  - Complexity
  - Waiting
  - Movement
  - Transportation

- Service wastes
  - Backlog of work
  - Errors in documents
  - Doing work not requested
  - Unnecessary process steps
  - Waiting
  - Unnecessary motion
  - Transport of documents

2.3.3. Flow

After defining the value from the customers' point of view, analyzing and mapping the value stream and eliminating the non-value-added activities, next thing that must be done is to create a continuous flow between value-added activities.

People have a common mind set saying that all tasks in a company must be grouped and similar tasks must be done in the same department. This enables people to do similar tasks in batches, which is easier to manage and seems more efficient. Also, the machines and equipments are busier. But all these 'efficiency' produce a lot of inventory, hidden defects, long queues and waiting times between processes (Womack and Jones, 2003).

In 1913, Henry Ford was the first to discover the power of flow. As it can be seen in Table 2.1, he decreased the effort needed to produce a Model T Ford by 90 per cent just by using the continuous flow in the final assembly line. But, it was a special case because they were producing high volumes using the same parts and for a long time. The real challenge was to use the continuous flow in environments where customers want a variety of products in small volumes, which is the general case. Taiichi Ohno achieved this by reducing the set-up times of machines and right-sizing them in order to put them adjacent to each other, so that the value flows continuously (Womack and Jones, 2003).

2.3.4. Pull

After eliminating the waste from the value stream and switching to a continuous flow, time required to meet a customer's demand decreases dramatically. This means that the company can stop pushing the products towards the customers and let them pull from the system. In a pull system, production rate is determined by the customer and none of the upstream processes produce anything before the downstream process pulls. The demand of the customer is transferred from the downstream processes to the upstream processes along the value stream. Pull system has many advantages:

- Inventory in the system reduces dramatically.
- Products that are not demanded by the customers are not produced.
- Workstations do not need a schedule.
- Bullwhip effect [1] towards the upstream processes is prevented.

[1] In a forecast based supply chain, each party keeps some safety stock in order to satisfy unexpected demand and this safety stock increase towards the upstream of the supply chain because of higher variation. The solution to this unwanted effect is to share demand information between each party, which is generally very difficult, or using kanban signals, for which an example will be given in section 2.4.3.

- The company becomes very flexible to the changes in demand (Womack and Jones, 2003).

2.3.5. Perfection

After realizing the four steps of lean thinking, everything becomes very transparent for each party along the value stream, including employees, subcontractors, suppliers, distributors and customers. This enables an immediate feedback from each party to improve the value stream. Since the inventory levels in the system are minimized, problems are detected and solved immediately and do not accumulate.

A lean value stream creates a win-win relationship for each party:

- Profitability of each firm increases.
- Employees not only earn more, but they also participate in decision-making and gain multiple skills.
- Customers get high-quality products and/or services with the exact features they want, at a reasonable price, at the right time and place.
- Suppliers become long-term business partners and they are supported to improve themselves.
- Resources of the countries are used more effectively and not wasted (Womack and Jones, 2003).

2.4. Opportunities for Improvement

In a typical mass production environment, people generally work with batches. This means long waiting times for each part or document in the queue. Value-added time is very short when compared to non-value-added times such as carrying and waiting. Rother and Shook (1999) claim that the biggest waste in a traditional serial production company is producing more and earlier than needed by the next process. Since your resources are busy with producing parts that are not yet demanded, you need additional capacity to fulfill your orders. This problem stems from traditional accounting metrics which calculate efficiency as parts produced per hour or day. In a mass production environment, you must produce parts as fast and many as possible, whether or not these parts will be used immediately or one week later. What should be the solution? Rother and Shook (1999) explain seven key methods to make a value stream lean.

2.4.1. Takt Time

Takt time is basically the demand rate of a company or a process. It is determined by the customer, whether internal or external. It is calculated as:

$$Takt\ Time = \frac{Available\ Work\ Time\ per\ a\ period}{Customer\ Demand\ per\ the\ same\ period} \tag{2.1}$$

For example, if a company works 1 shift 8 hours, less 1 hour lunch, less two 15 minutes breaks, and a customer demand 130 per day, then:

$$\text{Takt Time} = \frac{\text{390 minutes (6 hours 30 minutes)}}{\text{130 products}} = \text{3 minutes per product} \tag{2.2}$$

This means that the company must produce one product per every three minutes in order to satisfy customer demand.

Takt time is simply the heart beat of a company. In order to prevent overproduction, high amount of work in process and long queue times, all the processes of a company must work according to its takt time. For example, for an engine overhaul work, demand is 66 engines per year, and if we assume that total working days in a year is 300 after subtracting Sundays and national holidays, then the takt time for the engine overhaul is:

$$\frac{\text{300 days}}{\text{66 engine}} \approx \text{4,5 days per engine} \tag{2.3}$$

2.4.2. Continuous Flow

Continuous flow or one-piece flow is the superior way of production. It minimizes wait times and work in process between process steps. It also makes it possible to see the defects almost immediately. In a batch production environment, you see the defects after producing at least one batch of defective parts and start using these parts in the next process step, possibly after very long waiting times in the queue. In order to see the differences between batch and continuous flow production, let's assume that we have a production system of five process steps. First, we start producing ten products by using batches of ten. Second, we produce ten products by using batches of one, which is a one-piece flow production. Figure 2.1 shows the Gantt charts for two production systems and Table 2.2 shows the results.

As it can be seen in the results, one-piece flow production is 3½ times efficient than the batch production in terms of total time for ten products, eight times efficient in terms of responsiveness to demand and nine times efficient in terms of average work in process. Thus, one-piece flow should be applied in a production system wherever possible.

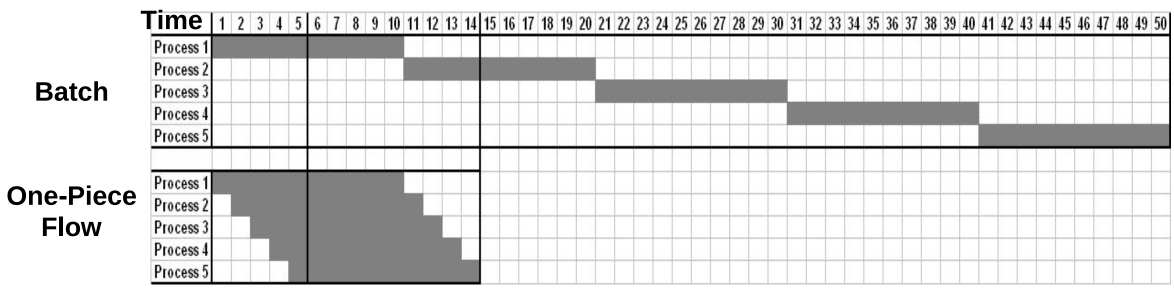


Figure 2.1. Batch vs. one-piece flow

Table 2.2. Results – batch vs. one-piece flow

	Batch Production	One-Piece Flow Production
Total time to produce 10 products	50	14
Total time to produce the first product	41	5
Average work in process	9*5 =45	1*5 = 5

2.4.3. Supermarkets

Rother and Shook (1999) state that there can be reasons that it is not logical or possible to implement a continuous flow between process steps. Below are the possible reasons for this:

- Some processes are designed to work at very long or short cycle times; or they need a die or model change to serve more than one product family.
- Some processes might be in a distant place, for example a far supplier. Thus, one-piece flow is not logical.
- Some processes might have a very low reliability or they might have very high cycle times, which prevent them to be connected to the other process steps with continuous flow.

For situations in which it is not possible to use a continuous flow, we should simply put a supermarket between process steps, which makes it possible to control the upstream process without making a schedule for it. A sample supermarket system can be seen in Figure 2.2.

"Pull kanban" can be thought as a shopping list for the downstream process. When the parts carrier of the downstream process comes and takes the needed parts from the supermarket, a production signal goes to the upstream process via production kanban. This really makes it possible to control the production rate of the upstream process without a need for scheduling. However, we should make sure that we implemented one-piece flow wherever possible in our process before using supermarkets.

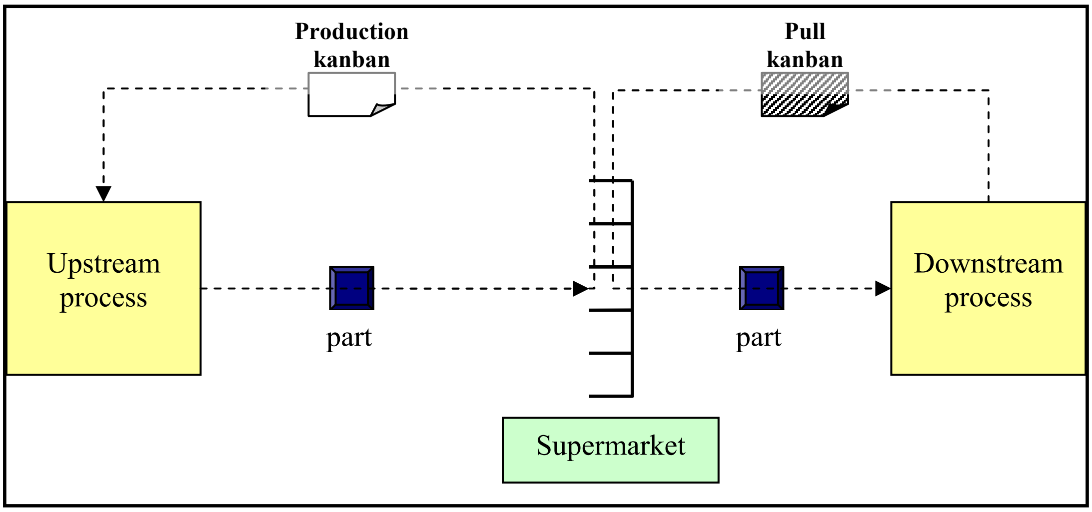


Figure 2.2. A supermarket system

2.4.4. Pacemaker Process

In a lean production system, you schedule only one process whose schedule is determined by the customer demand. This pacemaker process determines the tempo and schedule of the upstream processes. Pacemaker process is usually the last process connected to the upstream processes with continuous flow (Rother and Shook, 1999).

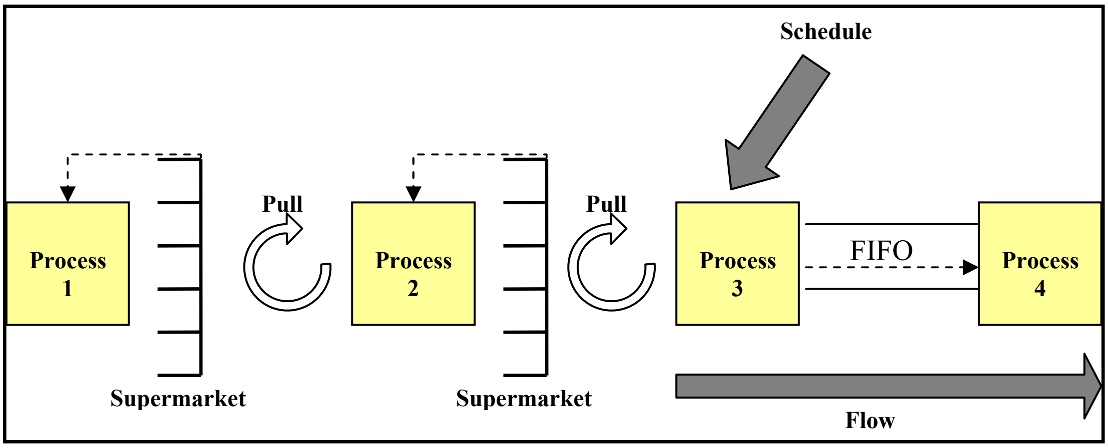


Figure 2.3. Pacemaker process

2.4.5. Production Leveling

In the pacemaker process, if you produce products in big batches, subparts and materials in the supermarkets of the upstream processes will also be consumed in batches, which in turn will increase the work in process inventory. Moreover, bullwhip affect will significantly increase the inventory levels in the processes at the start of the value stream (Rother and Shook, 1999).

In order to avoid this, we should level the production of different products in the pacemaker process. For example, instead of producing model A in the first shift and model B in the second, we should produce model A and B alternately in the same shift with small batches.

Leveling production in the pacemaker process reduces both final product and work in process inventory, but achieving a leveled production really requires some pain and smart work. You should prepare for frequent model changes by reducing setup times, making sure that your supermarkets always have the necessary parts and materials and making sure that your machines are always in good condition.

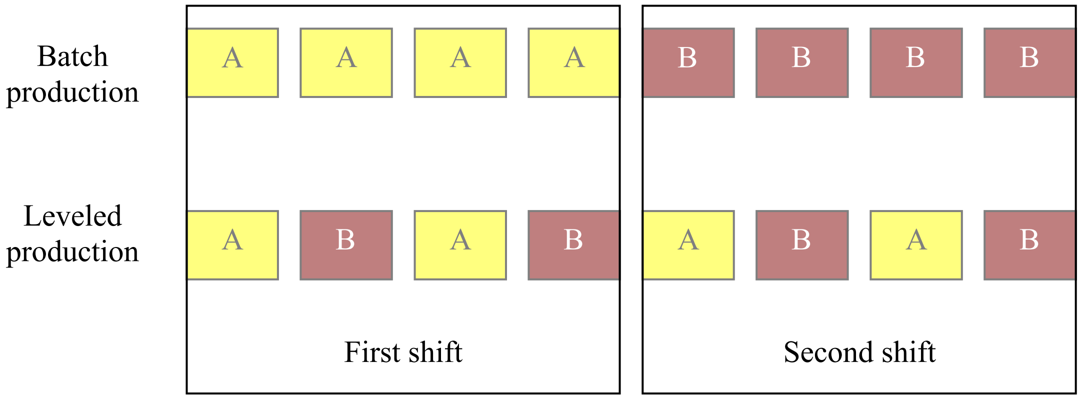


Figure 2.4. Batch vs. leveled production

2.4.6. Pulse

In section 2.4.1, it was stated that takt time is the heart beat of a company and all the other processes must work according to their own takt times. For example, if you use four of part A in a final product X and the takt time is 20 minutes for X. Then, takt time is five minutes for part A, which means that you must produce one part A in every five minutes to satisfy the demand for product X. Similarly every process must determine its takt time and produce according to it. Having a consistent and leveled production tempo makes it easier to see the problems beforehand and prevent them from occurring (Rother and Shook, 1999).

2.4.7. Every Piece Every

EPE stands for Every-Piece-Every and means the frequency of model changes in order to produce every different part. First, a lean production system should be able to produce every piece every day and then every shift, hour and pitch. In order for this to happen, setup times must be reduced to minimum and batch sizes must be really small. Consequently, upstream processes will be able to respond to the demand changes in the final assembly very quickly without having to keep a lot of inventory in the supermarkets (Rother and Shook, 1999).

Batch sizes can be determined by dividing the extra time in a day (according to takt time) with the duration of model change. For example, if you have eight hours and if it takes seven hours to produce the daily demand. Suppose that a model change takes 15 minutes. Then, you can change model four times a day (8-7 hours / 15 minutes).

2.5. Business Principles of Toyota

2.5.1. Long Term Philosophy

According to Liker (2004), the very first business principle of Toyota is to base management decisions on a long term philosophy, even though sacrificing short term financial targets. Unlike other companies, Toyota does not mention the quality of their products or earnings for their shareholders in the mission statement. Rather, they aim to create value for their customers, the society in which they do business and their employees. They know that profit and quality are natural outcomes of these long term goals.

Jim Press, Executive Vice President and C.O.O. of Toyota Motor Sales in North America and one of two American Managing Directors of Toyota, gives an example in Toyota Way (2004):

> *"…We wanted to have a distinctive Lexus-ride and wanted to break new ground in ride quality. To get that, our tire compounds were fairly soft. And so even though the customers experienced a good ride and the tires were well within our specs, they did not last as long initially as many customers wished. I think 5-7 percent of the customers actually complained about tire life. To us that is a big deal, as we are used to dealing in complaint levels of far less than 1 percent. So we sent the owners of every Lexus where these tires were specified a coupon they could redeem for $500 and apologized if they had any inconvenience with their tires and felt that they wore out early. Many of these were customers who had already sold their cars. The way you treat the customer when you do not owe them anything, like how you treat somebody who cannot fight back – that is the ultimate test of character..."*

This first business principle of Toyota is in perfect harmony with the idea that lean is not a project, but it is an endless journey towards perfection. Toyota has been on this journey for more than 50 years and they are still not perfect. Toyota, like every company, has waste in its processes. The common mistake made is thinking lean manufacturing as a set of rules and trying to apply them for some time without enough patience.

Grubb (2006) emphasizes this mistake:

"... but lean is not a "tool" to be applied here and there. It is not a tool at all; rather it is a business philosophy which focuses on the elimination of waste..."

Bradley and Willett stress the difficulty of creating a lean culture (2004):

"…Although the tools used in continuous improvement and kaizen projects are well known and easy to use, this observation implies that attaining success in a continuous improvement program is much more difficult than mastering the tools…"

Finally, Alukal states (2006) that:

"…Lean concepts are simple, but sustainable lean conversion is rarely simple. Success requires not only good change management policies, but also the integration of lean into the overall business strategy for the firm and into daily work for the employees…"

2.5.2. Process

2.5.2.1. <u>Continuous (One-Piece) Flow.</u> In Toyota Way (2004), Teruyuki Minoura, former president of Toyota Motor Manufacturing North America, explains one-piece flow:

"…If some problem occurs in one-piece flow manufacturing, then the whole production line stops. In this sense it is a very bad system of manufacturing. But when production stops everyone is forced to solve the problem immediately. So team members have to think, and through thinking team members grow and become better team members and people…"

In general terms, continuous flow is using smaller batches, positioning adjacent processes closer to each other as a cell if possible and making materials and information flow through these processes without any interruption.

Takt time is the heart beat of a company (and/or a process) and a complementary concept to the continuous flow. Liker gives the rowing example to explain the takt time better (1994). In a rowing team, there is a special member who keeps calling “row, row, row” to the rowers. S/he has a very critical task to keep the rowers in rhythm. If one of the rowers decides to row faster than the others, then the boat will slow down. It is the same in a company. If one process works faster than the takt time, it will create unwanted inventory (whether a component, semi-product or information). Liker numbers the benefits of continuous flow (2004):

- *Builds in quality.* Every process and employee is responsible for own quality. Problems are detected and solved immediately.
- *Creates real flexibility.* Production cell is more responsive to customer demand.
- *Creates higher productivity.* In a lean production cell, employees are measured in terms of value-added work rather than utilization rate of a mass production system, which includes overproduction and producing defective parts.
- *Frees up floor space.* Since inventory is minimized and right-sized equipments are put next to each other.
- *Improves safety.* Forklift transports and big batches of parts are minimized.
- *Improves morale.* Employees do more value added work and they see the results of their work immediately.
- *Reduces cost of inventory.* Inventory is converted to cash.

Creating a continuous flow production cell is painful and requires discipline, but it is worth to bear short term costs in order to gain a significantly more productive cell in the long term (Liker, 2004).

2.5.2.2. Pull System (Kanban). Traditional production systems push production by trying to predict customer demand and scheduling each production and purchase order. But, customer demand changes frequently in most of the times and system produces products and parts that are not needed. Also, some needed parts and materials are missing since they were not projected beforehand. Ohno established a system called *kanban*, where he can not use one piece flow. He formed small supermarkets between processes, where the downstream process pulls the necessary part and a production signal for that part is transferred to the upstream process mostly by kanban cards. Thus, the inventory in the system is controlled by these kanban cards, instead of very expensive scheduling softwares. Since every single inventory in the system is waste, the aim of such a system is to minimize the number of kanban cards and approach to a one piece flow system as much as possible (Liker, 2004). Grubb also emphasizes that bringing components and parts to the work area in recycleable containers allows us to use these containers as a kanban signal (2006).

2.5.2.3. Workload Leveling (Heijunka). Toyota aims to eliminate 3M's (Liker, 2004):

- *Muda – Non-value-added.* These are all activities that do not add value for the customer including complexity of processes, low productivity of labor, overproduction, low safety conditions, high energy usage, defects, using more than necessary materials, unnecessary usage of space, every kind of transportation and waiting, etc.
- *Muri – Overburdening people or equipment.* Forcing people or equipment to work faster than their natural limits.
- *Mura – Unevenness.* Having fluctuating workload from one period to the other. That results in the other two M's and necessitates having the capacity for the highest period.

Heijunka means leveling work load both in terms of volume and product mix. It also means a leveled purchase from suppliers and helps them reduce their finished good inventories. Companies generally attack muda first, since it is easier to see and eliminate. But mura is the source of other two M's and must be eliminated first by leveling the workloads of the resources (Liker, 2004).

2.5.2.4. Quality. Toyota's approach to quality is to design processes which prevent the operator from building defective parts (Poka-Yoke) and stop the line if the problem is not solved by the operator (jidoka or autonomation). In Toyota Way (2004), Gary Convis explains this:

> *"…So in all the years I've been with Toyota, I've never really had any criticism over lost production and putting a priority on safety and quality over hitting production targets. All they want to know is how are you problem solving to get to the root cause? And can we help you? I tell our team members there are two ways you can get in trouble here: one is you don't come to work, and two is you don't pull the cord if you've got a problem…"*

This approach is very hard to implement at first, since there are a lot of potential problems and the line stops very often. But discovering these problems and solving them continuously create a very strong culture for quality.

2.5.2.5. Standard Work. Standard work is the basis for continuous improvement and quality in Toyota. Liker quotes from Imai (1986) that, it is not possible to improve a process without standardizing and stabilizing it first. Otherwise, the improvements will be a better way of doing the task which is used rarely and will be omitted (2004). Liker also adds that if you ask a technician in Toyota how to work with zero defects, the answer would be "standard work". When a defect occurs, the first question asked is "Was standard work followed?".

Standard work necessitates bureaucracy, but in Toyota, it is enabling rather than coercive bureaucracy of Taylorism. Toyota sees worker not just someone to do the standard work, but also someone to think and find better ways of doing his tasks and solving problems. Workers have the authority to write their own procedures and these procedures are simple, practical and dynamic, since they can be changed easily according to changing work conditions and improvements. This makes Toyota very flexible, organic and adaptive company when compared to the other Taylorist companies (Liker, 2004).

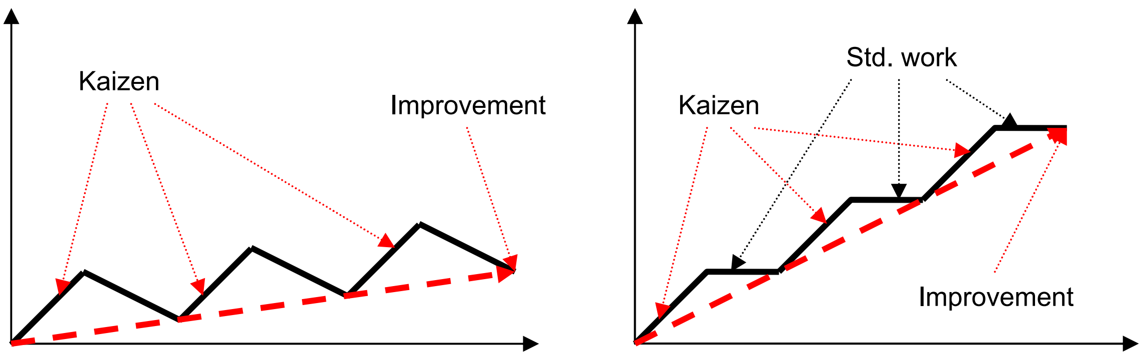


Figure 2.5. Non-standard versus standard work

2.5.2.6. Visual Control. Toyota does not use visual control in order to have a clean and shiny workplace, but they use it in order to improve the flow of value and make the problems more visible. Visual control also enables everyone to see if standard work is followed and process meets the takt time. 5S is the foundation for such a control, which can also be used in the office environment, such as establishing a visual filing system both physically and electronically, giving reorder points for the office supplies such as markers, papers etc. and managing e-mail's by deleting old ones and arranging incoming e-mails in a standard way (Liker, 2004).

In Toyota, everyone is very strict in preparing any kind of report as large as an A3 paper, which is the largest size of paper that fit into a fax machine. Rather than drowning in pages of raw information, they prefer explaining everything as visual as possible and in a summarized way (Liker, 2004).

2.5.2.7. Technology. Toyota sees technology as a means to support processes and people. They know that most of the processes contain non-value-added steps as well as value-added steps. By spending millions of dollars, a company can improve the value-added process steps, for example by buying a faster machine. On the other hand, the same amount of improvement can be achieved without spending any money, for example using kanban cards instead of scheduling each process step or leveling work loads of the process steps. Thus, before spending on technology, Toyota tries to get rid of all non-value-added process steps. Even they decide on a technology investment, they strictly analyze the reliability and effects of it and make sure that it supports people, processes and the value stream (Liker, 2004).

Flinchbaugh (2004) explains that people generally choose to invest in technology in order to solve problems, rather than focus on the process and find the wastes causing it. It seems to be spending money instead of using brains. For example, "instead of more forklifts, lean practitioners might end up with better inventory control. Instead of adding space, they might eliminate unneeded material and obsolete equipment."

Huls gives an example of using technology incorrectly creating waste in a process (2005). For example, in an office environment, if a process includes sanding e-mails, we should ask if the names in the distribution list are the correct ones who need that information and if the information sent is used or not. If the answer is no for one of these questions, then there is waste in the process.

2.5.3. Employees and Partners

2.5.3.1. Leaders. Technical tools of lean management, such as JIT, heijunka, kaizen and jidoka, are only effective when supported by a long term philosophy and a strong leadership. Leaders should teach these tools to the employees by applying themselves. This gives a very important message to the people, facilitates their buy-in and eliminates possible resistance.

Most of the companies hire leaders from outside the company, in order to make a major leap or put the company in order. However, leaders mostly come from inside the company in Toyota. They also have higher authority relative to their responsibilities, which is also uncommon for most of the other companies. Toyota managers have both technical and leadership skills and they try to develop people by leading through asking correct questions rather than giving top-down orders (Liker, 2004).

Bradley and Willet (2004) stresses the importance of leadership among other factors during the creation of a lean culture as below:

> *"…Lord managers believe that the most critical of these is leadership, which is manifested in a leader who has a vision for the future state of the business, communicates that vision, drives involvement and cultural change throughout the organization, and is on the shop floor daily expecting to see process improvements..."*

One of the most important tasks of a lean leader is to give the message that no one will be laid off because of any kaizen improvements. S/he must give the message that lean aims to eliminate waste, not people. He must also be able to create value-added tasks for the excess work force after improvements.

2.5.3.2. Teams. According to Mestre *et al*. (2000), the main challenge for the companies today is to integrate the efforts of their employees, giving them goals and motivating them towards the same direction. On the other hand, Autenrieth and Pfeiffer (1995) claim that, using individual and functional performance measures in a company blocks information and improvement sharing, and increases competition between departments.

Toyota puts teams and team members at the top of its hierarchy, since these are the ones who add value for the customer. All the others support these teams. Toyota has many team leaders for relatively few people. Almost everyone in the company has a leader who gives challenging targets and is also ready to give support when a problem occurs. Moreover, these team leaders are ready to work hands on whenever needed, for example substituting an absent team member (Liker, 2004).

Creating a team work culture and establishing a continuous improvement system requires overcoming people's natural resistance towards change. Employees, who involved in kaizen events and saw that changes happened and their ideas were used to improve their own tasks, like it better. On the other hand, employees who have not been involved in a kaizen event are nervous and they show the most resistance towards changes fearing that their tasks will be harder. Lean is not working harder; it is working smarter (Gary, 2006).

Liker (2004) states that Toyota has a reward system for zero absenteeism in its United States facilities. Every year approximately 60-70 per cent of employees deserve to enter a lottery for about 12 Toyota cars. He also adds that in Georgetown facility, employees gave almost 80.000 improvement suggestions, 99 per cent of which were implemented.

2.5.3.3. Business Partners. Toyota tries to establish a long term partnership with its suppliers. They try to help and support them in order to improve their processes and reduce their costs and inventory. This long term partnership creates a trust between each party, which is almost a must for a JIT system. Toyota makes sure to level its orders for the long term and in turn, expects from its suppliers to continuously improve their processes, quality, delivery performance and costs (Liker, 2004).

Liker also quotes from Taiichi Ohno (2004):

> *"...Achievements of business performance by the parent company through bullying suppliers is totally alien to the spirit of the Toyota Production System..."*

2.5.4. Problem Solving

2.5.4.1. Genchi Genbutsu. It stands for going and seeing the problem or situation at its place. In Toyota, people believe that numbers and words can give a general idea about the situation, but they are not enough to give every detail. So, in order to understand and solve the problem or make an improvement, you should go to the place of work. This is why Toyota managers prefer being closer to the factory floor and spend more time there (Liker, 2004).

Genchi Genbutsu is also effective for product development. You should go and see the preferences of your target customers in order to develop a new product for them. In this way, a lot of useful information can be gathered, which is unavailable otherwise (Liker, 2004).

2.5.4.2. Decision Making. "For Toyota, *how you arrive at the decision is just as important as the quality of the decision* (Liker, 2004)." Managers expect people to give a decision by using the correct process. Even though your results are not as good as expected, it will not be problem if the decision is made through the correct process. However, if you give a decision without supporting it with necessary facts and using the right process, it will not be appreciated even though your results are good.

A correct decision making process in Toyota has some characteristics (Liker, 2004):

- Decision should be made without hurry.
- All possible options should be considered.
- Every related party, that will be affected by the decision, should be included in the decision making process, even though they will not contribute much. This will help them buy in the decision and eliminate any possible resistance after the decision.
- An agreement should be achieved.
- As soon as reaching an agreement and making the decision, action should be taken.

Although all these characteristics seem to slow down the decision making process, Toyota is known for having the shortest new product development process. This seems illogical at first, but they eliminate all possible problems and resistance before reaching a decision (Liker, 2004).

2.5.4.3. Hansei and Kaizen. Toyota uses both standardization and innovation in a harmony for creating a learning organization. Whenever a problem occurs, first of all, they try to understand and clarify the problem in detail. To do this, going and seeing the problem at the place it occurred, genchi genbutsu, plays a critical role. After the real problem is understood, "Why?" is asked at least five times in order to find the root cause of the problem. After each question, a deeper cause of the problem is identified. If you stop asking "Why?" and try to solve the problem at any level, the problem will most probably occur again, since the root cause is not found and solved. After the root cause is determined, it is solved and standardized, so that it will not occur in future. In Table 2.3, Liker (2004) gives a good example on how to use "5-Why?" method to find and solve the root cause of a problem.

Hansei is a part of Japanese culture, which means feeling very sorry when you made a mistake and making a plan to solve it and make sure that it will not happen again in the future. It is being honest with our weaknesses and seeing them as opportunities for improvement. It is also finding something to improve even in a very good job. *Kaizen* supports *Hansei* by solving the problem and improving the situation (Liker, 2004).

According to Huls (2005), there are six roles in a kaizen workshop. These are:

- *Facilitators*: Experienced lean people from outside the process who are unbiased and neutral and keep the team on track. Other necessary competencies are general business knowledge, trust and respect.
- *Process experts*: People working in the process analyzed. They are the ones who know the process most and have the greater potential to produce improvement ideas if they are facilitated to think outside the box. If they are not facilitated or unable to think outside the box, they are the ones who can put the most resistance towards change.

- *Novice*: The inexperienced team member who is free to ask the most basic questions about the process.
- *Customer*: Internal or external customer who takes the value created by the process analyzed.
- *Support people*: People who are not directly inside, but who have support tasks for the process analyzed. For example, planning, IT, HR, etc.
- *Decision maker*: All the team members should be given the authority to make the changes needed for improvement ideas.

As Heston said (2006), Lean requires contribution from the operator. They are the ones who know the process better than anyone else and they are able to produce most of the improvement ideas.

Table 2.3. Asking 5-Why's in order to find and solve the root cause of a problem

	Problem	**Solution**
Why?	There is oil on the shop floor	Clean it
Why?	Because, it leaks from one of the machines	Fix the machine
Why?	Because, a gasket is in bad condition	Replace it with a new one
Why?	Because, the gasket is inferior quality	Change specifications
Why?	Because, we got a good deal	Change purchasing policies
	Because, purchasing department is evaluated on short term cost savings	Change the evaluation policy for purchasing department

According to Huls (2005), if the team members of a kaizen workshop do not know or understand the aim of workshop, they tend to defense their current processes and resist changing. Before participating in a workshop, team members should at least have the basic lean training and see the areas where improvements made in the previous workshops. Also, the aim of the workshop, the specific roles each member is expected to play and the basic rules should be explained to the team members before starting the workshop.

Mike Wynn, the vice president of Humantech, thinks that, all the resistance towards change seems to melt away when people see that they improve their jobs for their own benefit (Heston, 2006).

As Huls observed (2005), if managers are participating in a workshop as a team member, they tend to behave like a manager not like a team member. They tend to defend their processes and manage the team. Managers should be open to change and trust the team to make improvements.

3. MRO SECTOR

3.1. 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.

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.

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

- 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.

Flag-carrier airlines used to be owned by the state and their prestige were more important than their economic performance. Also, they used to provide a lot of jobs for the people. On the other hand, as the globalization gained momentum, economic performance became more and more important and most of the countries recognized that governments are not very good at running economic enterprises. As a result, most of the flag-carrier airlines became privately owned.

Privatization of these airlines resulted in a restructuring process for them. They started to separate most of the support functions like information technologies (IT), airport services, catering services and maintenance, from the airline and outsourced them. Moreover, these separated support functions started to restructure as profit centers and compete in the global market.

3.2. Background of Turkish Technic

Turkish Technic is an MRO company, which used to be the maintenance function of Turkish Airlines fleet. It separated from the airline in May 2006 and started to restructure as a profit center. Main services of the company are[2]:

- Line Maintenance
- Base Maintenance
- Engine Maintenance
- APU (Auxiliary Power Unit) Maintenance
- Component Maintenance
- Authorized Repairs

Turkish Technic is located at İstanbul Yeşilköy Atatürk International Airport and plans to build another MRO center on the Asian side of İstanbul at Sabiha Gökçen Airport. The company is located at a very strategic point in the world map. The circle, radius of which is three flight hours from Istanbul, includes 55 countries, which means a very large customer base for the company[3].

Turkish Technic has two maintenance hangars. The first hangar has 25.000 m^2 enclosed area and is big enough for serving two wide body and three narrow body aircrafts at the same time. On the other hand, the second hangar has 60.000 m^2 enclosed area and is big enough for serving three wide body and four narrow body aircrafts at the same time[4].

[2] Turkish Technic internal document
[3] Turkish Technic internal document
[4] Turkish Technic internal document

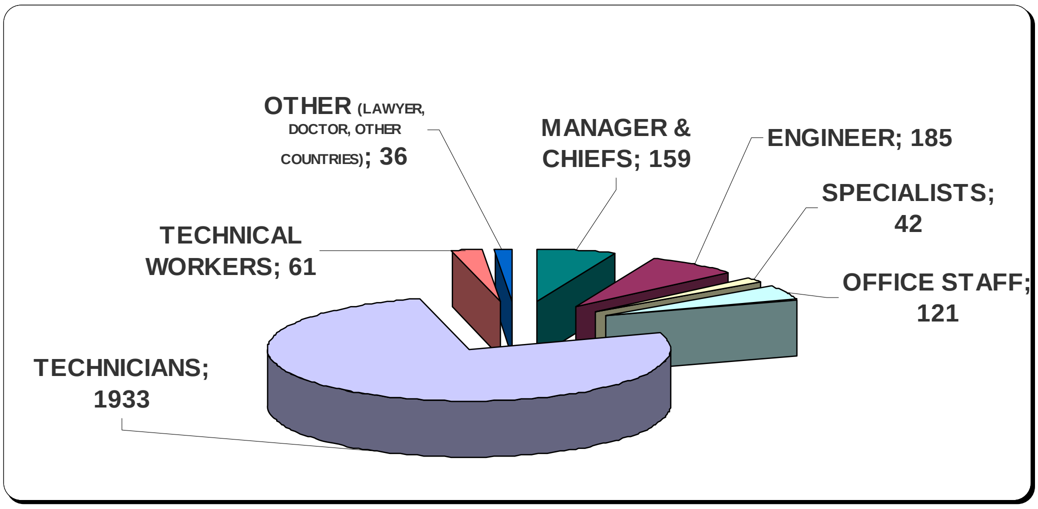


Figure 3.1. Employee structure of Turkish Technic (August 2007)

The company has approximately 2500 employees (August 2007), composed of 1933 technicians, 185 engineers, 159 managers and chiefs, 121 office staff, 61 technical workers, 42 specialists and 26 other (lawyer, doctor, employees in other countries, etc.)[5].

Turkish Technic has following certificates[6]:

- 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
- OHSAS 18001

Turkish Technic has base maintenance capabilities for following aircrafts[7]:

- Airbus 340
- Airbus 330
- Airbus 320 families

[5] Turkish Technic internal document
[6] Turkish Technic internal document
[7] Turkish Technic internal document

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

Turkish Technic has both international and domestic customers. Some of company's international customers are Lufthansa, Swiss Air, Malev Hungarian Airlines, TAP Portugal, Hamburg International, Donbassaero (Ukraine), Air Astana (Kazakhstan), Azerbaijan Airlines, Air Moldova, Bulgaria Air, Oman Air, Ariana Afghan Airlines and more. Some of the domestic customers are Pegasus Airlines, Onur Air, MNG Airlines, Freebird, Worldfocus, Kuzu Air Cargo, Atlas Jet, Iz Air, Sun Express, Inter Air, SKY Airlines, Cyprus Turkish Airlines and more.

3.3. Lean Manufacturing at Boeing

Before starting to explain the lean journey of Turkish Technic, it will be better to explain the lean journey of the consultant company, Boeing, which is a real success story in the aviation industry. "The Lean Journey at the Boeing Company", an unpublished work written by Pilla A. Leitner (2005) from Boeing Commercial Airplanes Lean Enterprise Office, was used as reference in this section.

In the 80's, Dr. Joseph Juran visited Boeing and the first quality and productivity circles were formed. Also, the Quality Improvement Center was formed in the Commercial Airplanes department.

At the beginning of the 90's, Statistical Process Control (SPC), Variability Reduction (VR) on military side and Hardware Variability Control (HVC) on commercial airplanes were started. Also, in the 90's, a program called World Class Competitiveness started. This was a program for benchmarking eight Japanese companies, each of which was "World

Class" in the world in some aspects. Program included a trip to Japan for managers and training for all 100 thousand Boeing employees taught by the managers. Managers prepared for the trip by attending 45 hours of class training and reading five books.

After the Japan tour, basic lean tools, such as 5S, began to be implemented. Propulsion Systems Division hired a consultant company and started to implement a full lean manufacturing strategy.

Boeing participated in Pratt & Whitney workshops and met Shingijutsu consultants Iwata and Nakao there, who were the students of Taiichi Ohno, the founder of the Toyota Production System. Then, in 1995, managers traveled to Japan to study Toyota Production System, hosted by Shingijutsu. Between 1995 and 1998, Boeing focused on Accelerated Improvement Workshops (AIWs) and conducted many of them. Then, they started to be taught the other modules by Shingijutsu consultants, such as Production Preparation Process (3P) and Heijunka (work load leveling).

At the start of the new century, Commercial Airplanes started Six Sigma program with GE engines and started to incorporate Six Sigma with Value Stream Analysis (VSA). At the same time, non-manufacturing processes started to be the focus of lean efforts. Also, Boeing started an enterprise-wide lean and six-sigma training.

Like automobile manufacturers, Boeing aimed to produce aircrafts in a moving line in order to achieve a continuous value flow to its customers. In order to accomplish this, Boeing developed nine tactics and called it the roadmap to achieve continuous flow:

1. Understand how value flows
2. Balance the line
3. Standardize work procedures
4. Put visual controls in place
5. Put everything at point of use
6. Establish feeder lines
7. Radically re-design products and processes
8. Convert to a pulse line
9. Convert to a moving line

Figure 3.2. Boeing 737 final assembly moving line (courtesy of Boeing)

Using Lean techniques, Boeing achieved:

- Pulse line for B717 final assembly in November 2000 and moving line in September 2001,
- Moving line for B737 final assembly in April 2001 (Figure 3.2),
- Moving line for B757 final assembly in August 2002,
- Moving lines for major subassemblies.

Results of Boeing's lean initiative were impressing. On the Defense Side, for the Mesa Arizona Apache helicopter program,

- cycle time was reduced 69 per cent,
- defects were reduced 90 per cent,
- and inventory turns increased from 3 to 78.
- Moreover, the site was awarded Shingo Prize in 2004 and 2005.

Commercial Airplanes parts plants reduced inventory by $1 billion in 1999. In Spokane, Washington floor panel manufacturing plant,

- cycle time was reduced 60 per cent
- and floor space 50 per cent.

In Renton, Washington, for 737 program,

- cycle time was reduced 46 per cent,
- stores inventory was reduced 59 per cent,
- work in progress inventory was reduced 55 per cent
- and factory floor was reduced 21 per cent.
- Flow time in final assembly for a 737 used to be 22 days. In five years, it was reduced to 11 days with a goal of 8 days.

After achieving moving lines, Boeing turned its focus towards the outside of the company. Considering the whole value chain, if suppliers succeed in making their processes lean, Boeing benefits from this in terms of reduced costs, improved lead times and quality. On the other hand, if customers succeed in making their processes lean, then again Boeing benefits in terms of increased sales. As a consequence of this view, Boeing Commercial Airplanes Lean Office started to give lean consultancy to customer airlines.

3.4. Lean Maintenance at Turkish Technic

As it was mentioned earlier, business model of the airline industry started to change in the 80's. Support functions, like IT, catering, maintenance and airport services, started to be separated from the airline and restructure as profit centers or these services started to be outsourced from specialized companies. The need for firms to control costs and maximize efficiency has become more important than ever. For an MRO company, becoming a profit center and competing in the global market requires having a high quality service and adherence to contracted terms for TAT (Turn Around Time).

In May 2006, as a result of this change in the business model, Turkish Airlines separated its maintenance function from the airline and started to restructure the new company, Turkish Technic, as a profit center. In January 2006, just before the separation, Process Improvement Department was formed and connected directly to the General Manager. At the same time, a contract for lean manufacturing consultancy was signed with the Boeing Company. Process Improvement Department was made responsible for the coordination of lean efforts and the deployment of lean philosophy throughout the company. The office was composed of one manager, one chief engineer (aerospace), two management engineers, one industrial engineer, one electronic engineer and one mechanical engineer.

In February 2006, the first two basic modules, 5S and AIW (Accelerated Improvement Workshop), were taught by Boeing consultants for two weeks. In the first week, classroom training took place and in the second week, three sample workshops were conducted.

In May 2006, second phase of the training, VSM (Value Stream Mapping) module, was taught by Boeing consultants in the first week and in the second week, two VSM workshops were conducted for the Engine Overhaul and B737-800 C-Check processes.

Since the beginning of the lean journey, the department, at which one of the members is the author of this thesis, completed 60 workshops (30 in 2006 and 30 in 2007), including 5S, VSM and AIWs.

4. BOEING 737-800 C-CHECK PACKAGE VSM

4.1. Methodology

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.

It is very rare to find a person in a company who knows all the processes, material and information flow of a product (Rother and Shook, 1999). Thus, VSM teams include at least one person from each department relevant with that main process, including support departments like HR and IT. This makes it possible for everyone in the VSM team to see the entire flow of that product and their tasks and contributions to the value stream.

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), whose applications in Turkish Technic are given in the fifth section. Huls described 12 steps of a VSM workshop (2005):

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

4.2. VSM Literature Review

In Table 4.1, recent VSM articles are compared to each other according to the application area and lean tools used. For example, 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. 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. Durmuşoğlu and Kulak (2008) used VSM for creating an office cell and reducing lead time. 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. 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. 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. Bushell and Shelest (2002) applied VSM in healthcare sector for reducing lead time. 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. Lastly, Arbulu and Tommelein (2002) applied VSM for reducing the lead time of a supply chain by reducing batch sizes.

Birgün et.al. (2006) conducted a VSM study at Uzel Company, which is one of the biggest tractor manufacturing companies in the world. They applied VSM techniques to hydraulic cover product family, because problems with the production of these parts directly affect the final assembly of tractors. First of all, they determined the takt time for hydraulic covers, and set the pre-assembly process, which is the last process in the value stream, as the scheduling point. They also put two supermarkets with kanban system in the value stream in order to provide a pull control. In the current state, supplier sends cover casts weekly and these are subject to an incoming test. Authors suggest improving the quality of supplier to level A, so that these parts are not taken to the incoming test. Moreover, they suggest making the supplier deliver cover casts twice a week instead of once, so that inventory levels will reduce. Other suggestions of the authors are applying Total Productive Maintenance (TPM) and 5S in the cell, in order to make sure that

Table 4.1. VSM articles

Article	Application Area					Investment Decision	Lead Time	Cycle Time	Poka-Yoke	Batch Size	Six Sigma	Kanban	Pull	Complex VSM	Cellular Approach
	Manufacturing	Office	Healthcare	Non-Profit	Supply Chain										
Birgün *et al.* (2006)	X						X	X		X		X	X		
Sullivan *et al.* (2002)	X					X	X								X
Durmuşoğlu and Kulak (2008)		X					X								X
Braglia *et al.* (2006)	X						X					X	X	X	X
Seth and Gupta (2005)	X						X	X		X		X	X		
Tatikonda (2008)		X					X		X	X	X				
Bushell and Shelest (2002)			X				X								
Mehta and Fargher (2005)				X		X	X								X
Krings *et al.* (2006)				X			X								
Arbulu and Tommelein (2002)					X		X			X					

machines and workplaces are always in good condition and problems can be determined pre-hand and solved before creating serious harm to the system. After all these improvements, they mapped the future state of hydraulic cover production process. According to the future state, cover cast inventory will reduce from 10,8 days to 2½ days and finished good inventory from 5 days to 0 days. Also, lead time of the process will reduce from 21 days to just 3½ days, meaning a six times faster inventory turnover.

Sullivan et.al. (2002) conducted another study on equipment replacement decision problem using VSM tools. They used VSM for making the decision of changing from a traditional batch production system with big equipments into cell production system with right-sized equipments. They analyzed the investment for changing to a cell structure by buying right sized equipment. They took into consideration the lost value of existing traditional production system, increase in product quality and throughput and decrease in work in process, floor space used and lead time. Even though they projected conservative improvement results by changing the hypothetical legacy production system into a lean production system, they found that it is more than feasible to make this decision.

Durmuşoğlu and Kulak (2008) established a methodology for building office cells by using axiomatic design principles. They justified that building office cells by using these principles will increase the performance of the processes and contribute to the competitive advantage of a company. They claim that cell structures divide complex processes into simpler and controllable units. In this paper, they did not only provide a methodology for forming and operating office cells by using axiomatic design principles, but also a real world example to show the results. They claim that most of the office processes contain too much waste inside and by finding and reducing these non-value-added operations, performances of office processes can be increased significantly. They also asserted that office cells provide better communication, control and teamwork between employees. Results of the study are significant. Building the office cell reduced the lead time by eliminating non-value-added process steps such as calling, sending e-mail, controlling and waiting. Instead of these non-value-added activities, cell members started to solve problems immediately by simply talking to each other and also assisted each other especially for the bottleneck processes. Moreover a visual communication board enabled everyone to see the performance and work load and improved the control and teamwork in the cell.

Braglia *et al*. (2006) established a methodology for applying VSM for products with complex Bill of Materials (BOM's). They claim that even though VSM is a very important tool for finding wastes and eliminating them, it can only be used for products that have a simple BOM and are produced in a linear process. They also asserted that the accuracy level of VSM is limited and in real world, most of the companies have more complex value streams. Thus, they proposed a new VSM method, composed of seven iterative steps, for flows merging together. The main objective of this method is to find the critical production path, that probably has shared resources with other paths, and improve it using classical VSM tools. Then, critical production path might change and the methodology is repeated iteratively until a desired level of work in process is achieved. Also, the authors showed the results of their methodology by applying it on a refrigerator production process, which is a real-world case study.

Seth and Gupta (2005) applied VSM tools for improving the processes of a motorcycle manufacturing company's supplier. They suggested hourly delivery from the supplier (ABC) to the main company (XYZ) instead of a shift-wise delivery. This will be controlled by a kanban system between two companies. Also, order quantity between ABC and second tier suppliers were reduced and this in turn decreased the inventory level in the whole supply chain. They also brought two jig lines closer and reduced the worker needed in these stations from 20 to 15. Also, a parallel manual welding booth operated by a highly skilled worker was proposed. Boring machine's cycle time was reduced by using an improved fixture. Moreover, they streamlined the cycle times of individual processes with the takt time and made sure that there is no process whose cycle time is greater than takt time. Results of the study are significant. Throughput per worker increased from 13,95 to 17,54 while lead time decreased from 3,22 days to 0,54 day. Finally, work in process inventory decreased from 466 to 90 and finished goods inventory from 700 to 360. Although results of the study are significant, Seth and Gupta warn that since VSM takes a snapshot of the process at that particular time, it might show the wrong picture. They also add that VSM shows only the waste inside the process but not how to solve them. Even though these drawbacks, they claim that VSM is still very powerful for seeing the big picture and showing the areas for improvement.

Tatikonda (2008) showed how to use lean six sigma techniques to find the root causes of billing errors, how to solve them and improve the billing process of a hypothetical company. Billing errors might be bills with wrong charge, bills sent to wrong customer or address, double or late billing, billing for unordered or returned goods, etc. Lean six sigma team of that hypothetical company prepared a Pareto diagram to find the most frequently occurred error. Then, they conducted a root cause analysis. Lack of communication and lack of knowledge and training were found the root causes of errors. The team prepared a current state map of the process. For the future state, the team reduced the process steps from seven to three. Also, they changed from a batch and queue system to a flow system, trained the employees for preventing the possible errors and made sure that data is entered into the system only once. Moreover, they put some poka-yoke checks in the system that alert users for possible errors and do not let them to progress with mistakes. The team also determined some performance measures to monitor the effectiveness of the billing process.

Bushell and Shelest (2002) applied VSM to progressive healthcare sector. The scope of their VSM was on a patient's appointment for primary care, having the service and leaving the facility. The team observed the current state of the process and found many kaizen items, such as very long waiting times, doing the same task more than once, asking the patient same things again, check-in more than once, etc. then, the team prepared two value streams for the future state: one for one year from now and one for five years from now. In the future state, lead time of the process will reduce significantly. The authors present another kaizen event in the same sector. In this study, the team discovers wastes such as an inconveniently placed fax machine, nurses searching for tools, doctors and nurses located far from each other, disorganized workplace, non-standard work, etc.

Mehta and Fargher (2005) applied VSM to a non-profit organization's process. Goodwill Industries collects and recycles clothes and some other goods. Most of the company's employees are disabled. A truck collects clothes from four stores and a donation center. Then, the truck is emptied and clothes are sorted by type, such as men's or women’s shirts, pants, tops, dresses, etc. The main problem with sorting is that there are huge amount of clothes waiting to be sorted. After sorting, clothes are inspected. Clothes employees believe will not sell are baled for auction and clothes rejected are also baled. After inspecting and sorting, employees attach price tags to clothes. Then, the clothes are shipped to stores. The current state map shows that cycle time for a piece of clothing is 27,8 seconds, whereas lead time is 19,85 days. Some of the kaizen items suggested by the team are doing the segregation in the stores and donation center instead of doing it after collecting clothes, designing containers for segregation, using cell structure wherever possible, building a washing, drying and ironing line for providing and selling high-quality clothes, improving ergonomics of the workplace, applying 5S and visual controls in order to simplify tasks and cross-training employees. After improvements, lead time will reduce to 0,66 day, revenues will increase by 40 per cent, value-added versus non-value-added ratio will increase, inventories between processes will reduce significantly.

Krings et.al. (2006) applied VSM in police recruitment process. When the team mapped the current state, it showed that time between the acceptance of a candidate’s application and his/her enrollment in the police academy is 20 months. This long period results in candidates’ giving up the process. The team produced kaizen items to improve the process. Some of these kaizen items are using electronic information flow instead of hard copy wherever possible, letting candidates schedule their meetings online themselves, joining some meetings or exams at the same day, minimizing wait times, etc. The team laid all of the kaizen items on a three months project plan. In the future state, lead time will reduce from 20 months to 13 months, meaning a 35 per cent improvement.

Arbulu and Tommelein (2002) applied VSM on the supply chain of pipe supports used in power plants. This VSM includes design, procurement and fabrication stages. Data was gathered by many interviews in order to measure value-added and non-value-added times, batch sizes and lead times. The main objective of the study is to determine the wastes inside the value stream and eliminate them in order to achieve a shorter lead time. In the current state, lead time for a typical pipe support is 28 to 37 weeks, whereas the cycle time is 42-52 hours. This mans that only 4 per cent of the total time is value-added. Waiting to be processed (batches) and rework are determined as two main reasons of these non-value-added times. Also, the authors mapped the fabrication phase in detail. Kaizen items produced by the authors are minimizing batch sizes, involving suppliers in design phase, establishing supplier collaboration, avoiding designing the pipes more than once, standardizing products and processes, improving communication between each party in the supply chain, improving supplier selection process, etc.

During literature survey on VSM, unfortunately no studies conducted in an MRO company could be found. Main contribution of this thesis is that it contains a VSM study conducted in an MRO company. Moreover, C-Check Package process is unique to an MRO company and it deals both with office and hangar environments. This is another different aspect of this thesis. Although one of the main improvements for the future state is to found a new office, it does not include a major investment decision. This can be done by placing different functions in the same area as an office cell. Workloads and employee numbers for each process step in the cell should be determined by time and method analysis and this is subject to future research. Both cycle time and lead time are reduced significantly by reducing the batch sizes to one-piece-flow and doing the tasks concurrent with maintenance instead of doing them in a batch flow after maintenance. Poka-yoke, six-sigma, kanban, pull and complex VSM tools are not used in the study.

4.3. Boeing 737-800 C-Check Package Process

Maintenances of aircrafts are controlled by a maintenance program. This program includes different types of maintenances (checks) for a certain aircraft model. These maintenances differ from each other in terms of application period and detail. For example, the maintenance program of Turkish Technic for Boeing 737-800 aircrafts is as follows:

- Ramp Check : Applied every five days
- Line (L) Check : Applied every 300 flight hours or one month (whichever occurs first)
- A Check : Applied every 600 flight hours or two months (whichever occurs first)
- C-Check : Applied every 7000 flight hours or two years (whichever occurs first)

Each aircraft maintenance is accomplished by using a package composed of:

- Task cards: Routine maintenance cards determined by the aircraft manufacturer.
- Engineering orders: Major modifications requested by the aircraft manufacturer and assigned by the maintenance engineering department.
- Component change cards: Cards used for changing a component that is about to complete its maintenance interval.
- Hold cards: Cards postponed from the previous maintenance.
- Engine maintenance cards: Cards related with engine maintenance.
- Non-Routine Work Items (NRWI): Items added to the package during the maintenance, such as corrosion, dent, damage correction, etc.

Preparation of a C-Check package starts approximately ten days before the aircraft goes into the hangar for maintenance. A boardroom is determined for each aircraft in order to control the maintenance and the package is prepared and placed in the boardroom before the maintenance. After the maintenance, Technical Controllers (TC's) check the package, approve the maintenance and release the aircraft to service. Then, the package is closed on TAMES (Turkish Airlines Maintenance Engineering and Inventory System), scanned, indexed and sent to the archive. Only after indexing, invoice can be prepared and sent to the customer.

Many departments participate in the C-Check Package process, each doing a small part of the whole. First of all, Maintenance Engineering (ME) prepares the task cards according to Maintenance Planning Document (MPD) provided by the aircraft manufacturer (Boeing in this case). They determine the intervals and thresholds of each task card, which are the two most important parameters. Cycle is defined as one take-off and one landing of an aircraft and threshold is the minimum cycle to include this task card in the maintenance package. For example, if the threshold is 5000 and interval is 1000 for a task card, after the aircraft reaches 5000 cycles, this card is included in the maintenance package and applied every 1000 cycle. ME also assigns task cards to aircrafts. Since one task card might not be effective for new and old versions of the same aircraft model (B737-800 for example), ME has to check the effectivity of each card and assign it to specific aircrafts on the TAMES system. Although ME prepares the most important contents of a maintenance package (task cards), their tasks are not package specific. In other words, they do not repeat their tasks for each maintenance package. Actually, their tasks are periodic. For example, they determine the intervals of task cards once a month. This leaves ME's tasks out of the scope of this VSM.

Package process starts with Production Planning and Control (PPC) specialist to start preparing the maintenance package on the system. Using the monthly maintenance plan, planner gets the task card list automatically from the system. Then, planner checks if there is any:

- hold cards
- engineering orders
- component change cards, and
- engine cards

for the aircraft and adds these cards in the package, if there is any. Also, planner makes reservation for components if there is any component change card. After the planner prepares the package on the system, s/he gets:

- a cover page showing the work orders, entry and release dates of the aircraft, etc., and
- indexes for each type of maintenance card

as hard copy documents.

Then, cover page and indexes are sent to the airline for control and approval. Airline very rarely requests change in the package. These changes might be adding or removing a specific card.

After the airline approval, cover page and indexes are sent to Maintenance Planning and Control (MPC) department, which is on the mezzanine floor. Here, the whole package is printed according to the work order prepared by the planner. Then, barcodes and stickers are prepared and stuck on the cards. Cards are sorted according to skill codes necessary to accomplish the card, for example mechanical, structural, avionic or cabin interior skills. Priority cards are determined and separated. These cards are major tasks of maintenance such as initial cleaning, incoming tests, engine removal, galley removal and tasks related with fuel tank. Application order of the cards are determined and prepared on the MS Project. Task cards are transferred to MS Project in order to see the completion percentage for each task. Then, all cards are arrayed on the board according to skill codes and the area of the aircraft (Figure 4.1). Priority cards are placed on the Boardman's desk. Boardman is the responsible coordinator of maintenance and he is generally an experienced head technician. During the maintenance, completed cards are given to the maintenance planner. S/he checks seals and man-hours of the cards and files them. Maintenance planners also follow up the cards sent to back shops.

Towards the end of the maintenance, Technical Controllers (TC's), who has the authority to release the aircraft to service, start checking the seals on the cards and compare the cards with indexes in order to see if there is any missing card. If there is no problem TC affixes a seal and releases the aircraft to service.

After the maintenance, the package is sent to Maintenance Planning and Control (MPC) and Non-Routine Work Items (NRWI's) are entered into the system. Here, the package is also checked in order to find if there is any missing man-hour data on the cards.

Figure 4.1. Boardroom

Then, the package is sent to PPC control room on the second floor. Here, component change cards, aircraft, engine and component Engineering Orders (EO's) are closed and their man-hour data are entered into the system. Task cards assigned to work order are checked if there is any open on the system. Engineering departments sometimes request a result report for EO's. These result reports are photocopied and sent to related engineering department. Indexes are checked and if there is no problem, work order is closed on the system. A report is prepared for the package explaining the missing items, if there is any. Then, the package is sent to the Technical Controller (TC) of the airline.

After the TC of the airline approves the maintenance, the package is sent first to the archive and then to the scanning room on the mezzanine floor. Here the whole package is scanned and indexed. Only after indexing is completed, customer relations department can start preparing the invoice of the maintenance.

4.4. Current State Map (CSM)

Part of the process before maintenance is important for an MRO company, since reducing the time needed for preparing the package means planner can prepare the package closer to the maintenance. So, it reduces the risk of aircraft waiting in the hangar for a maintenance package. Also, it enables the package to be more accurate and current including all last minute changes. This reduces the risk of reprinting the indexes of the package, which happens quite often in the current circumstances.

On the other hand, part of the process after maintenance is much more important for an MRO company. Reducing the time necessary for preparing and sending the invoices to customers after maintenance means collecting money earlier from them. If we think that a C-Check is about 200-700 thousand dollars depending on the content of the package and NRWI's and if we assume that an MRO company accomplishes 30 C-Checks a year, it means collecting approximately 15 million dollars earlier from the customers. This is an extremely important financial competitive advantage.

Thus, a VSM workshop was planned in order to improve the C–Check package process of Turkish Technic. The scope of the VSM included:

- Preparation of the package on the TAMES system
- Taking the print-out of the package and sorting task cards according to skill codes
- Accomplishment of the maintenance
- Controlling and closing the task cards physically
- Controlling and closing the task cards on the TAMES system
- Sending the package to the archive
- Scanning and indexing the package

So, the boundaries of the VSM were from preparation of the package on the TAMES system to indexing the package. Deliverables of the VSM were:

- Creating a cell structure in which the package is flowed continuously without interruption
- Reducing the time necessary for preparing the maintenance package
- Reducing the time necessary for indexing the package after maintenance
- Reducing the cycle times of each process step
- Eliminating unnecessary steps in the TAMES system
- Increasing productivity
- Eliminating unnecessary checks in the process
- Eliminating multiple handling in the process

Data collection was conducted by actually observing individual processes and doing time and method analysis. Distance between departments was measured by a wheel meter. Package is transferred from one office to the next in batches. For example, packages are transferred from PPC to MPC twice a day. If we take one day as eight work hours, expected wait time for the package between these two departments is two hours. The package is transferred from PPC to archive once a week. So, expected wait time between these two offices is 3½ days (7/2). After all data collection was completed, current state of the C-Check package process was mapped and it can be seen in Figure 4.2 and Figure 4.3.

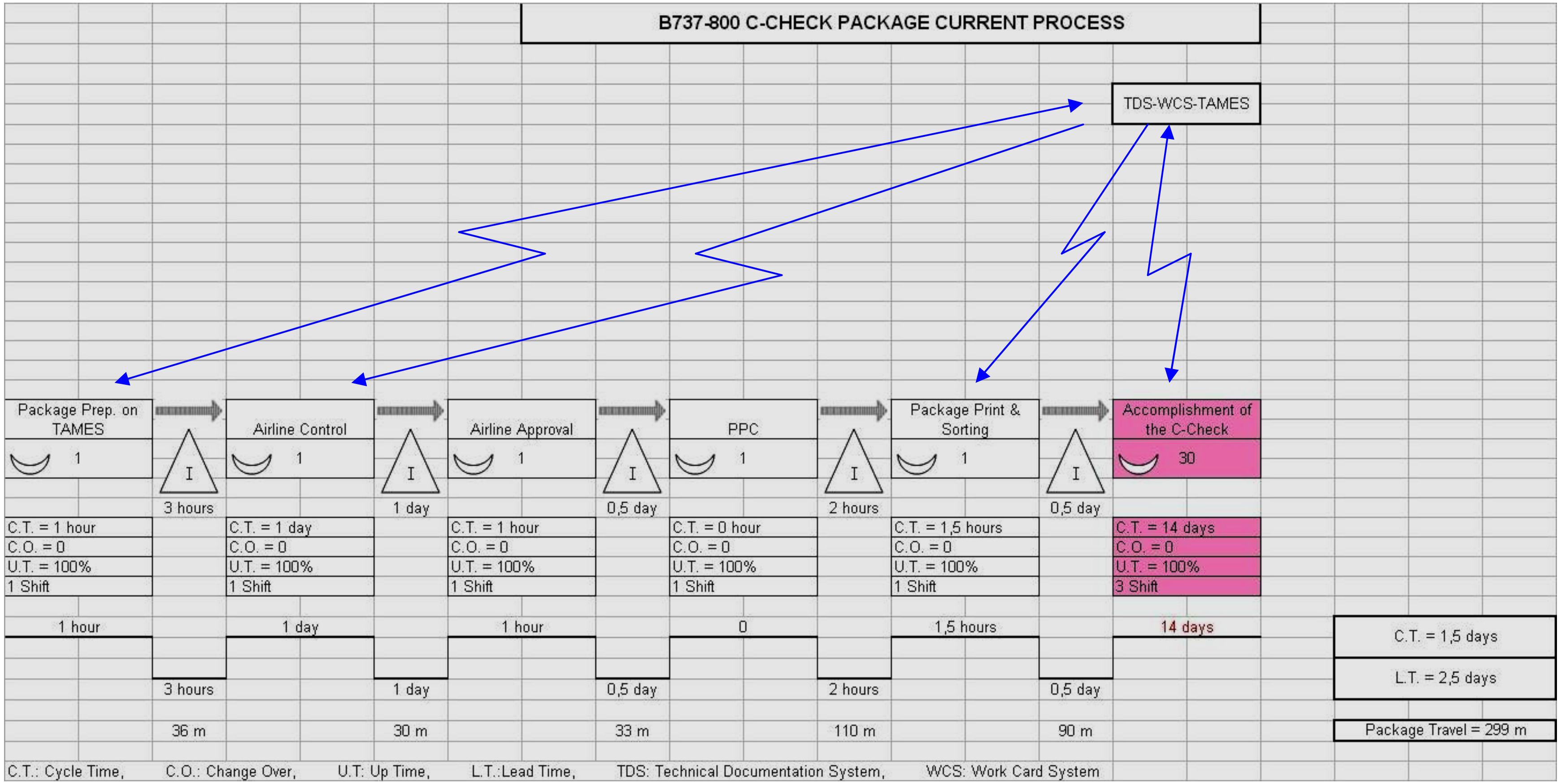


Figure 4.2. Current state map (before the maintenance)

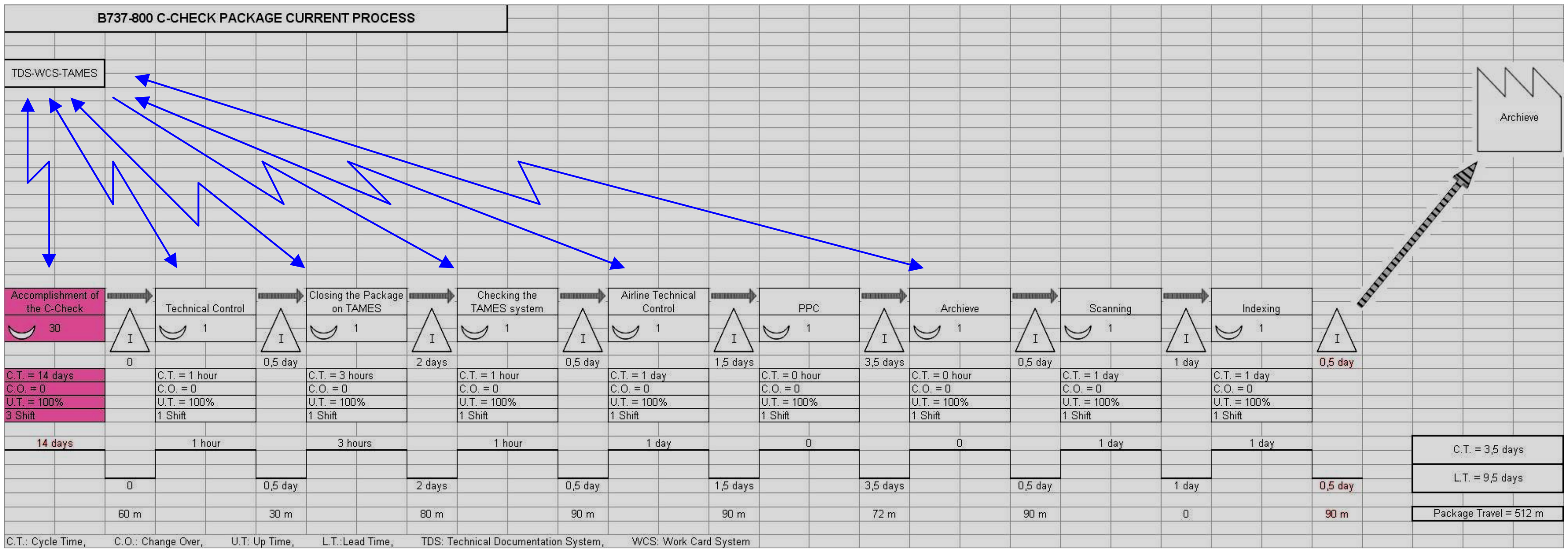


Figure 4.3. Current state map (after the maintenance)

Please note that 14 days of C-Check is out of the scope of this study and is not included in the calculations. Also, since we are able to prepare the invoice after the package is indexed, we are not interested in the tasks after indexing.

As it can be seen from the figures, in the current situation, package travels 811 meters and visits 14 offices during its journey. Total cycle time for the package is five days including

- airline control (1 day),
- airline approval (1 hour),
- airline technical control (1 day),
- scanning (1 day)
- and indexing (1 day).

The first three are the processes of the customers and they could not be observed in detail. Besides, it is not possible to intervene with these processes, at least in the short term. Scanning and indexing are accomplished by a subcontractor company and these could not be observed in detail, either. Lead times are taken as cycle times for these five process steps. They most probably contain a lot of waste inside, but this is out of the scope of this VSM and subject to future studies.

Even though the actual work on the package is five days, it waits seven days in the process for being taken to the next office. This duration is totally non-value added and unnecessary and it shows that the package is not processed continuously. One primary aim of this VSM is to minimize this duration and package travel by creating a cell and make the package flow continuously without interruption.

4.5. Improvements and VSM Plan

The major improvement suggested for the future state of the process is to found an office named Maintenance Support and Follow-Up (MSFU) on the hangar level and make sure that all tasks after the maintenance are completed in this cell during the maintenance as one piece flow, instead of completing these tasks in batches after the maintenance.

Suggested layout for this office can be seen in Figure 4.4 and its effect on the future state is shown in Figure 4.6 as “MSFU” kaizen burst.

In the current situation, closing task cards on the system is the responsibility of the technician who completes the task. This creates some problems:

- Task cards should be opened on the system when the technician starts the task and they should be closed on the system when the task is completed. A technician completes three-four tasks on average during one shift and they generally open all tasks at the same time when they start their shifts and they close them when they complete their shifts. This results in the inaccuracy of man-hour data on the system.

- Technicians generally wait in the computer queue for opening their tasks at the start of their shifts and closing their tasks at the end of their shifts.

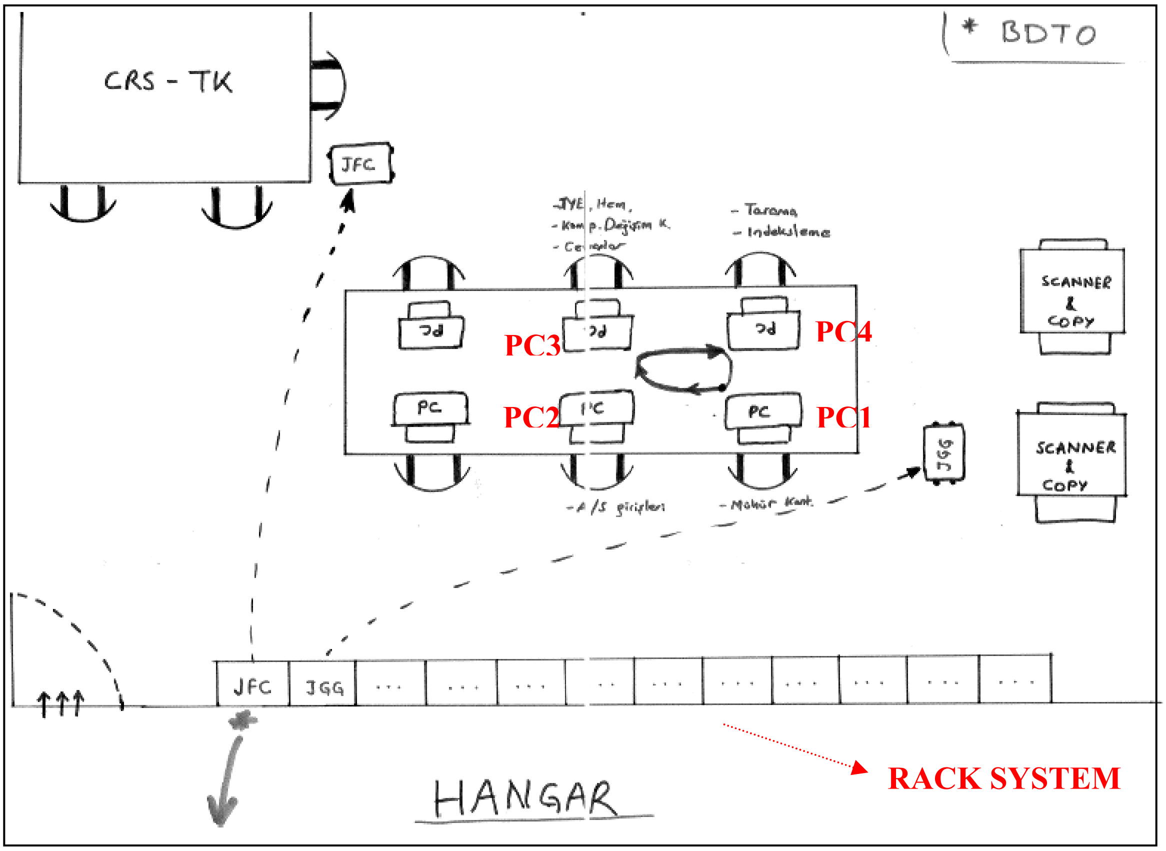


Figure 4.4. Maintenance Support and Follow-Up (MSFU) office

- Technicians are qualified personnel for an MRO company and they are supposed to work on the aircraft for value-added work. Closing task cards on the system is a non-value-added but necessary task that can be done by basic office clerk.

The second major improvement is building a rack system in front of this MSFU office in order to control the maintenance documents better (Figures 4.4 and 4.5). Each aircraft has a boardroom, in which incomplete cards are placed on the board according to the skill codes and the area of the aircraft (Figure 4.1). When a task card is completed, technician closes it on the system and gives the card to maintenance planner in the boardroom for checking and filing. In the future process, when the technician finishes a task card or his shift ends, he will just put the card in the appropriate slot for his aircraft (Figure 4.5). This kaizen burst is shown in the future state of the process as "Rack System" (Figure 4.6).

JFC	JGG	...	...
Closed cards/items	Closed cards/items	...	...
Open cards/items	Open cards/items	...	...
Processed open cards/items	Processed open cards/items	...	...
30	30		
35	35		
40	40		
51	51		
Other	Other		
Cards/items with missing seal	Cards/items with missing seal	...	...
30	30		
35	35		
40	40		
51	51		
Other	Other		

Figure 4.5. Rack detail

For example,

- When he completes a task card, he will just put it on the "closed cards/items" shelf of the related aircraft (JGG for example). Office clerk, working at PC1 in the MSFU office (Figure 4.4), will collect the cards on this shelf periodically and check seals. If any seal is missing s/he will put the card in the proper slot in the shelf named "Cards/items with missing seal". In this shelf, numbers represent the skill code of the card. So, for example, an avionic technician will check only his slot in this shelf.

- If there is no missing seal, employee working at PC1 will pass these cards to the employee at PC2. Here, man-hours of the cards will be entered into the system. Then, employee PC2 will pass the cards to PC3 (Figure 4.4).

- Some tasks take longer than one shift and cannot be completed during a shift. Technicians will put cards of such tasks on the “open cards/items” shelf of the rack. Employee working at PC2 will periodically collect these cards and enter their man-hours into the system in order to make the data available to see what percentage of an individual card or the whole maintenance is complete. Then, s/he will put these open cards on “Processed open cards/items” shelf for each skill code (Figure 4.5). So, the technician working in the next shift will also check this slot in order to see if there is any open card.

- At PC3 (Figure 4.4), Engineering Orders, Non-Routine Work Items (NRWI’s) and Component Change Cards will be closed on the system. Also, since bodies of the NRWI’s are written in handwriting by the technician who detected it, these texts should be entered into the system. PC3 will also enter these data into the system at this point in the process. Then, the cards will be passed to PC4.

- At PC4 (Figure 4.4), cards will be scanned and indexed. Then, they will be put into a wheeled cart just below the aircraft’s column in the rack. This wheeled cart will belong to technical controllers and cards inside it are ready for technical control.

- At the current circumstances, technical controllers conduct seal checks and some of the other routine tasks. They are very experienced and qualified technicians who have the authority to release the aircraft to service. In the suggested system, these routine tasks will be completed by office clerks and technical controllers come into the MSFU office for one or two hours a day to complete their tasks on the package at the CRS-TK desk in Figure 4.4. This change will free them up from routine low-quality tasks and they will be able to spend more time with critical tasks such as engine run-up, pressurization, fuel tank tasks, etc…

- Tasks conducted in batches after maintenance will be conducted during the maintenance as one-piece-flow. Thus, when the maintenance is completed, the package will have already been processed and ready for technical control of the airline.

Other kaizen items about the process are below:

- Task cards generally give reference to AMM (Aircraft Maintenance Manual) document which is accessible through intranet. Technicians spend some time both waiting for a free computer and searching for the relevant pages. Attaching AMM pages to task cards might be an improvement which will eliminate these non-value-added (NVA) times. But first of all, a time study should be conducted for a representative sample of task cards, in order to see how much time a technician spends on average for these NVA process steps during his shift. Also, time and paper needed to prepare these AMM pages should be taken into consideration. Moreover, AMM pages should be current in order not to miss any changes about work procedures. So, they should be printed out closer to conducting the task. This requires a reliable system to make sure that all AMM pages are up-to-date.

- Planner has to enter skill codes, man-hours needed and some other data for each Engineering Order manually while preparing the package on the system. These data are constant and already in the system. A change in the system should be made in order to make sure that these data come to planner's screen automatically. The effect of this improvement can be seen in Figure 4.6 as "Auto Data Entry" kaizen burst.

- Two transactions need the text of NRWI and they do not talk to each other. Thus, these data are entered into the system twice. A system change should be made in order to make sure that there are no multiple entries into the system. The effect of such a change is shown on the future state of the process as "Talking Transactions" kaizen burst (Figure 4.6).

- In the Maintenance Planning and Control (MPC), when the package is being printed out, Engineering Orders (EO's) are taken out of files, photocopied and put back. In other words, EO's are used in hard copies. They should be made available on the intranet, so that they can be printed out with the package. This kaizen burst can be seen in Figure 4.6 as "Electronic EO".

- After the package is prepared in PPC, cover page and indexes are sent to the airline. On the other hand, MPC can not start printing the package even though it is ready on the system. They need the hard copies of the indexes. Also, airline approves the package as prepared 95 per cent of the time and they request some additions or subtractions of package content five per cent of the time. So, a suggestion might be sending the hard copies of the indexes directly to MPC and sending the soft copies of the indexes and the cover page to the airline. While airline checks the indexes and approves the maintenance, the package might be printed out in MPC. When the airline approves the package, they sign the cover sheet and this sheet might be added to the package which has already been prepared. If airline wants to add or remove some cards, these changes can be done on the prepared package. "Electronic Transfer" kaizen burst in Figure 4.6 represents this improvement on the future state.

A proposed plan to achieve the future state of the process is given in Table 4.2. Please note that there is a finish-to-start relationship between implementation steps.

According to the plan, first of all, a room should be arranged for simulating the new process. Necessary hardware should be provided for this room (PC's, scanners, tables, etc.). Employees should be selected from the related departments for simulation. User ID's should be defined on these PC's and necessary authorization for using the transactions should be given. Then, a C-Check package should be selected for simulation. Simulation should be announced to all related departments.

Table 4.2. Implementation plan for the new process

#	Implementation Step	Deadline
1	Arranging a room for simulation	28.03.2008
2	Providing necessary hardware (PC's, scanner, etc.)	28.04.2008
3	Employee selection for the simulation	30.04.2008
4	Definitions and authorizations	01.05.2008
5	Choosing a C-Check package for simulation	02.05.2008
6	Announcing the simulation to all related departments	03.05.2008
7	Simulation (B737-800 C-Check)	03.06.2008
8	Determining problems and solving them	30.06.2008
9	Second simulation	30.08.2008
10	Determining problems and solving them	22.09.2008
11	Two checks at the same time (B737-800 C-Check)	30.10.2008
12	Three checks at the same time (B737-800 C-Check)	31.12.2008
13	All types of aircrafts (C-Checks)	30.03.2009
14	All types of aircrafts and checks	30.06.2009

The chosen package should be processed according to the new process and results should be recorded. There will certainly be problems during the simulation. These problems should be determined and solved before conducting the second simulation. Simulations can be repeated until the new process is smooth enough. Then, the new process should be tested by processing two and three packages at the same time. Next, the new process should be extended to the C-Checks (or equivalent checks) of all type of aircrafts and finally to all types of aircrafts and all types of checks.

4.6. Future State Map (FSM)

After completing all kaizen items, the new process will be as in Figure 4.6. Note that airline control and approval are conducted concurrently with package print and sorting. When the airline completes its control and approval, the package will be ready. And if there is any change request about the package content, these will be done on the prepared package. Also, PPC box after airline approval is eliminated since this process step is only for distribution. There is no task done on the package at PPC step. It is only used as a distribution center. In the future step, since the indexes are sent directly to MPC, there is no need for a distribution center.

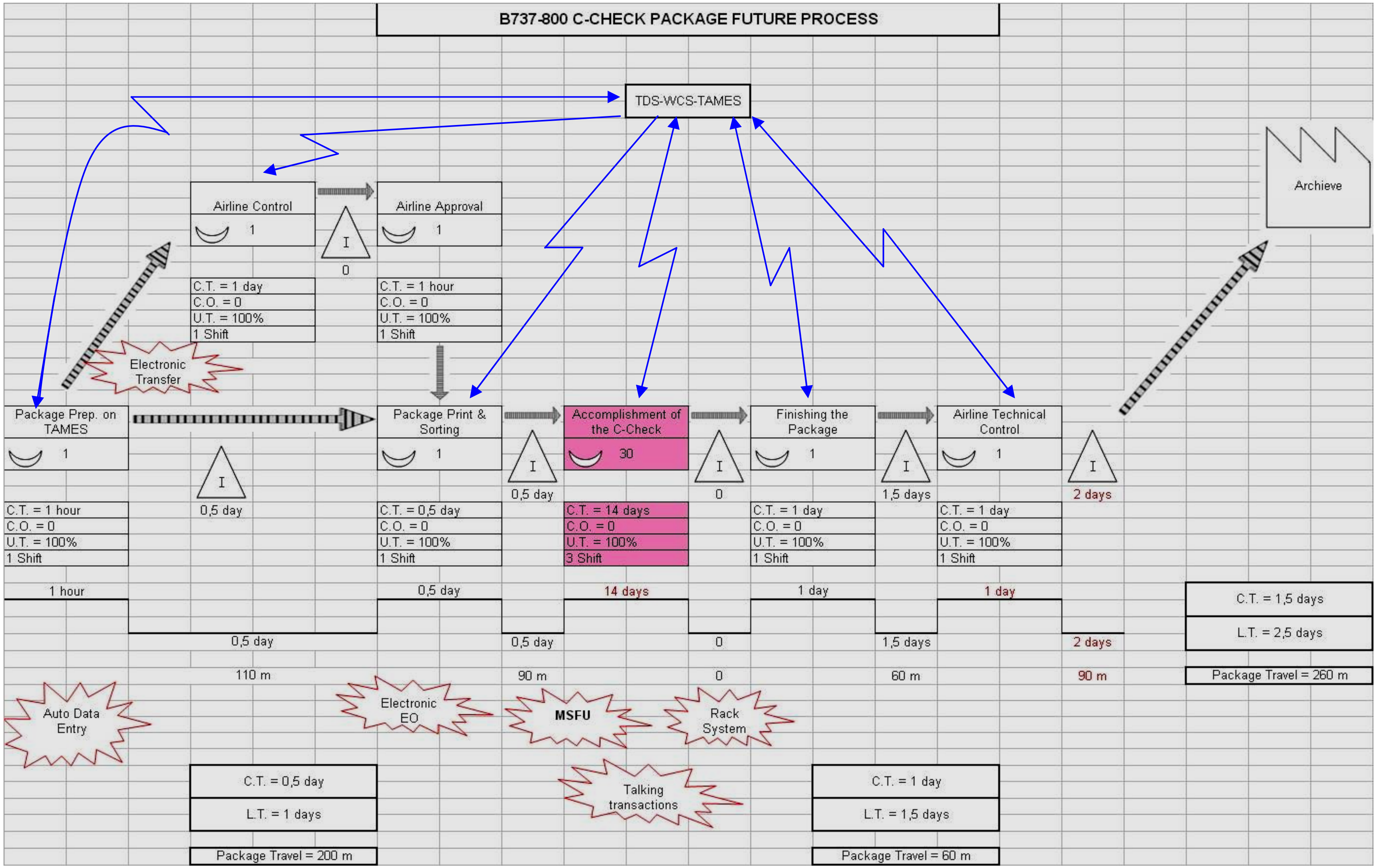


Figure 4.6. Future state map

More importantly, since the tasks done after maintenance will be conducted concurrently with the maintenance as one-piece-flow, there will not be any of these process steps after the maintenance. However, a process box for "finishing the package" should be added, since there will certainly be some problems at least during the transition process. After the transition to new process is complete, another VSM can be conducted to improve the process further. After the package is finished, it will be sent to customer's technical control for approval as usual. Then, the package is sent to the archive.

Please also note that the primary objective of this VSM is to prepare and send the invoice to the customer as soon as possible. In the future process, we will be able to prepare invoice after the airline's technical control approved it. Since, the package is scanned and indexed during the maintenance, airline will not have to wait the whole package for technical control. They will be able to conduct their control during the maintenance just by checking the completed task cards on the system.

Although we are able to prepare the invoice after "finishing the package", one day for airline technical control in the future process was left intact, since it is an improvement affecting airline's internal process. So, this time is not included in the results. Also, 14 days of C-Check time is not included in the results, since the duration of the check is out of the scope of this VSM.

4.7. Results

If we divide the whole C-Check package process into two parts as "before the maintenance" and "after the maintenance", results of the VSM are given in Table 4.3.

At the current situation, package travels 299 meters during the processes before maintenance. Sending the indexes directly to MPC instead of sending it first to the airline and then to PPC and MPC will reduce the package travel to 200 meters, which is a 33 per cent improvement.

Package is processed 1½ day before the maintenance at the current situation. In the future process, airline control and printing out and sorting the package will be conducted concurrently instead of one after the other. This will reduce the cycle time to ½ day, which is a 66 per cent improvement.

Package waits 1½ days without being processed just for somebody to take it to the next office. By sending indexes directly to MPC and eliminating PPC distribution center, lead time will be reduced from 2½ days to 1 day, which is a 60 per cent improvement.

After the maintenance part of the process was more important and was the primary focus of this VSM. Package travels 512 meters after the maintenance is completed. By founding the Maintenance Support and Follow-Up (MSFU) office on the hangar level and making sure that all tasks after the maintenance are completed in this cell during the maintenance as one piece flow, package travel will reduce to just 60 meters, which is a 88 per cent improvement.

Package is being processed 3½ days after the maintenance. By changing from functional silos and batches to MSFU cell and one-piece-flow, all tasks conducted after the maintenance will be conducted concurrently during the maintenance. This will reduce the cycle time to just 1 day, which is a 71 per cent improvement.

Most significant result will be on the lead time of the package after maintenance. At the current situation, it visits eight offices before going to the archive and waits six days (Lead Time – Cycle Time) between offices without being processed. By bringing all functions into MSFU cell on the hangar floor, this will reduce lead time from 9½ days to just 1½ day, which is a significant 84 per cent improvement.

Table 4.3. Results of the VSM

Process Before Maintenance	Current	Future	Improvement
Package Travel	299 m	200 m	33%
Package Cycle Time	1,5 day	0,5 day	66%
Package Lead Time	2,5 days	1 day	60%

Process After Maintenance	Current	Future	Improvement
Package Travel	512 m	60 m	88%
Package Cycle Time	3,5 days	1 day	71%
Package Lead Time	9,5 days	1,5 day	84%

Even though a company achieves high profits, it might go bankrupt if it fails to manage its cash flow. Thus, cash flow is maybe the most important financial aim of every company. Companies spend money for producing the good or service for their customers. They spend money for buying necessary parts, tools, raw materials, technology, paying wages of their employees, paying overhead costs and many more things. The gap between spending money to satisfy your customers' demands and collecting your revenues from customers is critically important in financial terms. In this VSM, if the future state is achieved, Turkish Technic will be able to collect its revenues approximately ten days earlier. If we take into account that maintenance and engineering revenues of the company, which is around 300 million dollars a year, it is like collecting this amount of money ten days earlier.

5. KAIZEN WORKSHOPS IN TURKISH TECHNIC

5.1. 5S WORKSHOPS

5.1.1. Methodology

Weber (2005) quotes Art Smalley stating that:

"…In a low volume, custom-build situation, the typical waste is having to look for tools, parts, information to complete the job…"

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.

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

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.

Success of a 5S program depends on the buy-in and active participation of all employees, monitor and evaluation of the efforts and rewarding the best performers. But, before all of these, every employee should have a basic knowledge of lean management and 5S. Also, the aim of the 5S program should be explained to everyone very well.

5S stands for 5 Japanese words that start with 'S', namely Seiri, Seiton, Seiso, Seiketsu and Shitsuke. These Japanese words were translated into English as: Sort, Simplify, Sweep, Standardize and Self-Discipline.

Sort

This is the first step of a 5S program and it simply means touching every single item in a workplace and separating the unnecessary from the necessary. Here, item means every part, material, component, tool, document, hardware etc. When the unnecessary items are determined, we should either remove them from the workplace or give them to another department which may need.

Here, unnecessary items can be unsafe, outdated, unused, defective, duplicate or excess items. In our 5S workshops we encountered documents kept for years but never needed or tools hidden under other tool crates that no one knows that they are there. So, touching every single item is extremely important in this step. Moreover, sorting must be conducted together with all the employees working in the area in order to make sure that we are not removing any item needed.

During sorting, it is possible to feel unclear about whether an item is necessary or unnecessary. For such items, a quarantine area must be defined and those items must be stored there for a specific time period. It is 6 months for shops and 1 month for offices in Turkish Technic. During this time, if these items are used, then they must be defined as necessary and placed in a dedicated place; if not, they must be defined as unnecessary and removed from the workplace.

Simplify

After removing all the unnecessary items from the work area, the second step is to determine a dedicated place for every single necessary item. Usage frequency, ease of reach and ergonomics principles should be kept in mind while determining places for necessary items. For example, items most frequently used should be placed at the point of use.

"A place for everything and everything is in its place!". The aim of simplifying is to make it possible for everyone to find anything s/he needs in the shortest time possible just by identifying and looking at the dedicated place for that item. So, visual control plays a critical role here. Everything should be marked, labeled, color-coded, outlined in order to help understanding,

Sweep

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.

Standardize

This step means making signs, definitions, labels, targets, color codes or other efforts standard throughout the company, so that everybody will be able to speak the same language and results will be comparable. It also includes the standardization of improvements which means applying improvements made in one area to other possible work areas.

Self-Discipline

Self-discipline is the hardest step of a 5S program. It means that employees internalize all the methods and principles of 5S and they do not need an external control or direction. It can be achieved by developing and continuously improving 5S policies and following the improvements and standards.

5.1.2. 5S for Stands & Ladders in Turkish Technic

Overview

One of the first workshops conducted in Turkish Technic was a 5S workshop for stands and ladders. These stands and ladders are used for reaching the different areas of an aircraft during maintenance. Currently, Turkish Technic has base maintenance capabilities for ten different aircraft models. These are:

- Airbus 340
- Airbus 330
- Airbus 320 families
- Airbus 310
- Airbus 300
- Boeing 737 classics
- Boeing 737 new generations
- British aerospace RJ 100/85/70
- Gulfstream aerospace corp. G-IV
- Cessna 172

For all these aircraft models, there are different stands and ladders with different height, area, shape or slope, designed for reaching the different areas of an aircraft (Figure 5.1). Those different areas are:

- APU (Auxiliary Power Unit)
- Nose
- Under wing (Right/Left)
- Front door
- Rear door
- Front cargo
- Rear cargo
- Tail
- Main Landing Gear (Right/Left)
- Engine (Right/Left)
- Pylon
- Winglet (Right/Left)

Figure 5.1. A front door stand for Airbus 330

Problem Definition and Motivation

At the time of the workshop, there were 137 stands and ladders, some of which can be used for multiple purposes. Those stands and ladders stay in an open storage area between two maintenance hangars. When an aircraft is taken into the hangar, technicians go and find the necessary platforms for the maintenance and carry them into the hangar using their wheels. The problems with the initial state of the area were:

- They were so disorganized that a technician was not able to know if there is any proper stand for his task.
- Even though he finds one, there were most probably other stands blocking his way.
- There was a waste of searching and carrying.

So, a 5S workshop was planned to organize the area, so that every technician would be able to find and take the proper stand for his task easily. An initial photo of the area is shown in Figure 5.2.

Figure 5.2. An initial view of the stands & ladders area

Deliverables

As it can be seen in the charter document of the workshop in Figure 5.3, the deliverables of the workshop were:

- Manufacturing new stands and ladders for necessary aircraft model-area combination
- Placing stands and ladders closer to the places they are needed, in order to minimize technician travel
- Improving safety and ergonomics of stands and ladders
- Determining transport ways for the area and a specific place for each type of stand and ladder, in order to minimize the time needed for technician to find and carry the necessary stand or ladder
- Removing or modifying unused stands and ladders in order to use the space effectively

Figure 5.3 shows the charter document for stands and ladders 5S workshop:

WS: 0608

CHARTER DOCUMENT
04-14 APR 06

5S FOR STANDS AND LADDERS

SCOPE:

REARRENGEMENT OF THE LADDERS AND STANDS

BOUNDARIES:

FROM THE STARTING OF REARRENGEMENT OF LADDERS AND STANDS
TO MAKING STABLE THE NEW SITUATION OF THE LADDERS AND STANDS.

DELIVERABLES:

MANUFACTURING NEW STANDS AND LADDERS
REDUCTION OF PEOPLE TRAVEL
PROVIDING SUITABLE PLATFORM
ELIMINATION OF SAFETY ITEMS
FACILITATING THE FLOW OF THE LADDERS AND STANDS
REMOVING THE NO-USAGE PLATFORM

LEADERSHIP APPROVAL:

Y. ÖZER	C. ÜNSALAN	Rıza Memişoğlu	M. YILMAZ	M.TİLLA
A/C O/H Coord.Chief	A/C O/H Coord.Ch.	O/H Equipment Shop Ch.	A/C O/H Shop Mng.	Bussiness Development Mng.

Figure 5.3. Charter document for stands & ladders area 5S workshop

Sorting and Simplifying

A detailed analysis was done in order to determine the necessary number of each stand and ladder. While doing this, the team took into consideration the substitute for each stand. A substitute stand is the one with similar shape and height that can be used at the same area of the aircraft. Final of the analysis can be seen in Table 5.1.

According to this analysis, the unnecessary items were removed from the area (Figure 5.4). These were:

- Obsolete stands and ladders that belong to old aircraft models, such as Boeing 727, and can not be used for other models. Some of these were removed from the area and some were modified for the other aircraft models.
- Unsafe stands and ladders. Some of these were repaired and some were scrapped.
- Excess stands and ladders that belong to formerly very popular aircraft models, such as Airbus 310, and now are needed very rarely. Some of these were removed from the area and some were modified for other aircraft models.

Table 5.1. Analysis of necessary stands and ladders for each aircraft model-area combination

LADDERS AND STANDS

Type	MLG	ENGINE	PYLON	WING	CARGO	TAIL	APU	FSG	DOOR
A340	6	15	A310 PYLON (2)	A310 KANAT (4)	A310 KANAT (2)	A310 APU/ KAPI (1)	1	HANGAR PLATFORM	A310 APU (1)
A330	A340 MLG (2)	A310 MOTOR	STEP	A310 KANAT (4)	A310 KANAT (4)	A310 APU	HYD. MOB. PLATFORM	HANGAR PLATFORM	A310 APU (1)
A320-21-19	BUILT NEW	STEP	737-400 KARGO	4	310 MLG (1)	A310 KANAT (1)	HYD. MOB. PLATFORM	HANGAR PLATFORM	BUILT NEW
A310	10	8	7	10	8	2	5	2	1
737-800	1	STEP	STEP	6	737-400 KARGO	1	737-800 TAIL	HANGAR PLATFORM	2
737-400	1	STEP	STEP	2	13	3	737-400 TAIL	HANGAR PLATFORM	1
RJ100	-	A310 MOTOR	RJ100 KANAT	2	STEP	FIXED PLATFORM	737-400 KARGO	5	2
STEP	22								
VIP Helicopter	1								

(a)

(b)

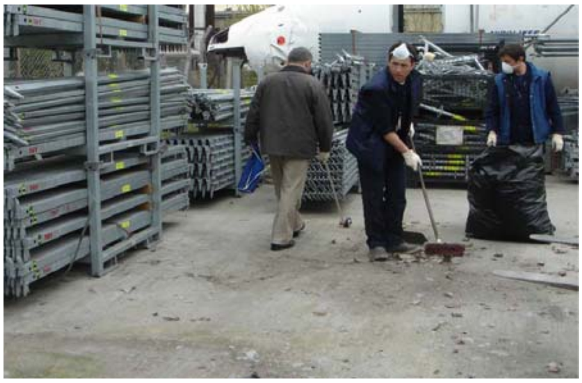
(c)

(d)

Figure 5.4. Determining the unnecessary items (a and b) and removing them from the area (c and d).

Sweeping

After removing the unnecessary items, the area was cleaned deeply (Figure 5.5).

(a) (b)

Figure 5.5. Cleaning the work area (a and b)

Standardization and Improvements

The team came up with many improvement ideas for the area. Here are the most important ones:

- The team decided to give a color code for each aircraft model and organize the area to dedicate a specific place for each stand and ladder according to this color code (Figures 5.6 and 5.7). These color codes are also being used for tool crates and many other purposes.
- Four additional Boeing 737-800 door stands production
- Airbus 320 (A320) Main Landing Gear (MLG) and door stands production
- Putting placards on stands and ladders specifying each usage area for each one. For example, B737-400 Cargo and A319/320/321 Pylon stand.
- Monitoring the usage of each stand and ladder for six months, in order to determine the unnecessary ones.
- Painting four legs of each stand and ladder with the decided color code (Figure 5.7.c).

Figure 5.6. Color codes for each fleet

(a)

(b)

(c)

(d)

Figure 5.7. Color codes were given to dedicated areas (a and b) and stands (c) and floor (d) were painted according to these color codes.

Results

Below are the results of the workshop:

- A lot of space was gained by removing the unnecessary items from the area.
- The storage area was organized by giving color codes for each aircraft model and placing the stands and ladders for each aircraft model to a specific place.
- Places for stands and ladders were determined by the need and frequency of usage. For example, A310 stands were placed closer to the old hangar, whereas A320 stands were placed closer to the new hangar.
- Also, a transport way was reserved in the middle of the storage area to make the transport of the stands easier.
- Unsafe stands and ladders were repaired.
- The technicians are now able to find the proper stand for their tasks almost immediately and in good condition; and then take it easily from the area.

5.1.3. Tool Shop 5S

Overview

Next 5S workshop was conducted in the general tool shops. There are two tool shops in Turkish Technic, one in the first hangar and one in the old hangar. Normally, each technician has a personal toolbox for small and general purpose tools, such as screwdriver, etc. Other big or special tools are stored in these tool shops. Before starting a task, each technician goes to the tool shop and gets the tools necessary for his/her current task.

Problem Definition and Motivation

Below are the problems with the initial state of the area:

- Improper, broken, unsafe, untidy and heavy tool crates
- Using big crates for very small tools
- Safety and ergonomics problems, such as heavy tool crates without wheels or improper storage of some tools.

- Some crates were stored on top of others. So, it was not easy to know which tool is inside the crate below. Even though the technician knows that the tool he needs is in the crate below, it was very hard for him to reach and take it, because he has to remove all the other crates first.

Initial photos of the tool shop can be seen in Figure 5.8.

Since a significant portion of the tasks need a big or special tool, there are frequent visits to the tool shops. This adds a set-up time and even a queue time in the early steps of each task and accumulates as an important waste.

(a) (b) (c) (d)

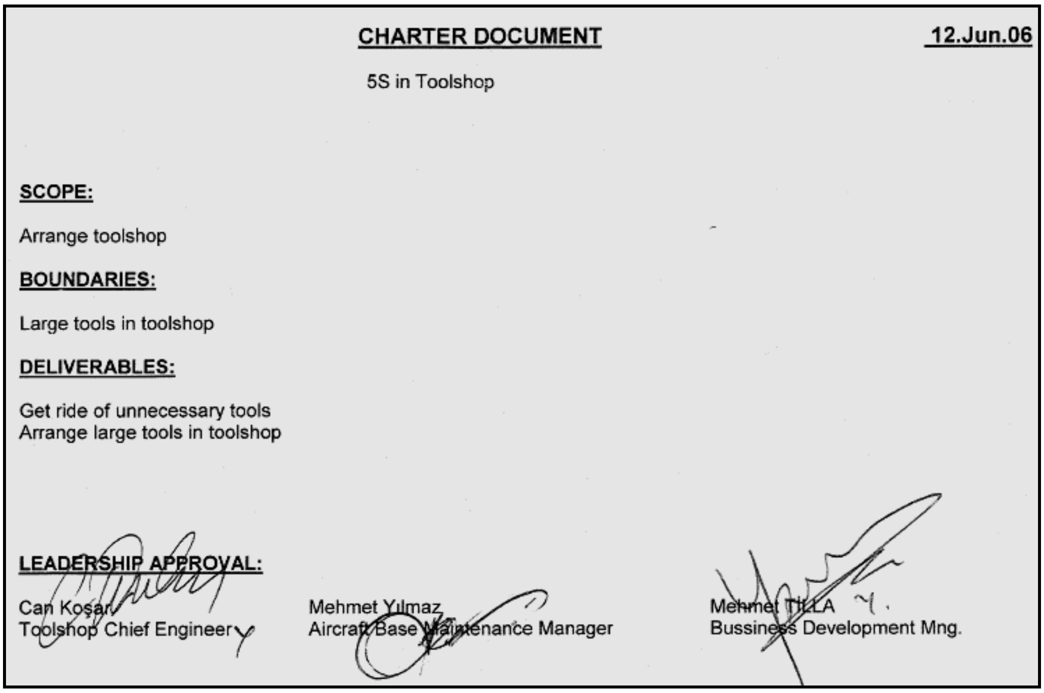
Figure 5.8. The initial state of the tool shop (a and b). A big crate used for small tools (c). Improper storage of some tools (d).

Deliverables

As it was summarized in the charter document of the workshop in Figure 5.9, the deliverables of the workshop were:

- Removing the unnecessary tools, in order to gain space and use the area more effectively
- Determining a specific place for each tool, in order to minimize the time needed for technician to find and take the necessary tool for his/her task
- Using the same color codes with stands and ladders for the tools of different aircraft models, in order to make the are more visual
- Improving safety and ergonomics of the area

Figure 5.9 shows the charter document for tool shop 5S workshop:



CHARTER DOCUMENT **12.Jun.06**

5S in Toolshop

SCOPE:

Arrange toolshop

BOUNDARIES:

Large tools in toolshop

DELIVERABLES:

Get ride of unnecessary tools
Arrange large tools in toolshop

LEADERSHIP APPROVAL:

Can Koşar
Toolshop Chief Engineer

Mehmet Yılmaz
Aircraft Base Maintenance Manager

Mehmet T[illegible]LA
Bussiness Development Mng.

Figure 5.9. Charter document for toolshop 5S workshop

Sorting and Simplifying

First, the team started to touch every single item to determine which tool is necessary and which one is not (Figure 5.10). In order to do this sorting, the team needed to look at the data for the usage statistics of all these tools. One part of the analysis can be seen in Table 5.2.

According to this analysis, unnecessary tools were determined and removed from the area (Figure 5.11). Also, some light tools were taken from the carts and hanged on the wall. These both freed up space and provided an ergonomic reach for the tools.

Figure 5.10. Sorting - separating necessary from the unnecessary.

Figure 5.11. Unnecessary items removed from the area

Table 5.2. Usage statistics of tools

Box No	Tool	THY P/K	P/N	Size (cm)	Fleet	EA	Usage per month
1	ENGINE BOOTSTRAP KIT	TE10013	C71020-76	98*134*87	E	1	1
2	ENGINEBOOTSTRAP	T910029		45*135*84	1	2	1
3	BOOTSTRP	T171008		55*160*76	1	3	1
4	RAIL SET	T910017		64*164*83	9	1	3
5	HORIZONTAL STAB.REMOVAL	T710594		273*143*1	7	1	2
6	MINI LIFT	T910028		52*250*35	9	1	3
7	FLOW TEST KIT-RAT	TG29518		80*100*122	G	1	3
8	COVER PRIMARY NOZZLE	T110576	RSE1082	130*130*13	1	4	4
9	PLUG-NOZZLE AND INNER BOD	T910730		145*145*12	9	4	4

Sweeping

After removing the unnecessary items, the area was cleaned deeply (Figure 5.12).

Figure 5.12. Photos of the area after removing all unnecessary items and cleaning

Standardization and Improvements

Below are the other improvement ideas developed by the team:

- Putting wheels under the carts of heavy tools, so that it is easy to carry and use them (Figure 5.13.a)
- Marking the positions of the crates on the floor, so that each crate has a specific place
- Taking small tools out of the big crates and putting them in smaller tool kits (Figure 5.13.d)
- Making a hanging system on the wall for light tools (Figure 5.13.b)
- Taking the light tools out of the crates and hanging them on the wall (Figure 5.13.c)
- Drawing shadows of the tools on the wall, so that every tool has a specific place
- Using a barcode system to track the tools
- Repairing and painting some old crates
- Putting labels and color codes on the crates and tools so that it is easy to see which tool is inside a crate and which fleet that tool belongs to. Here, the same color code with the stands & ladders was used in order to standardize the improvements.

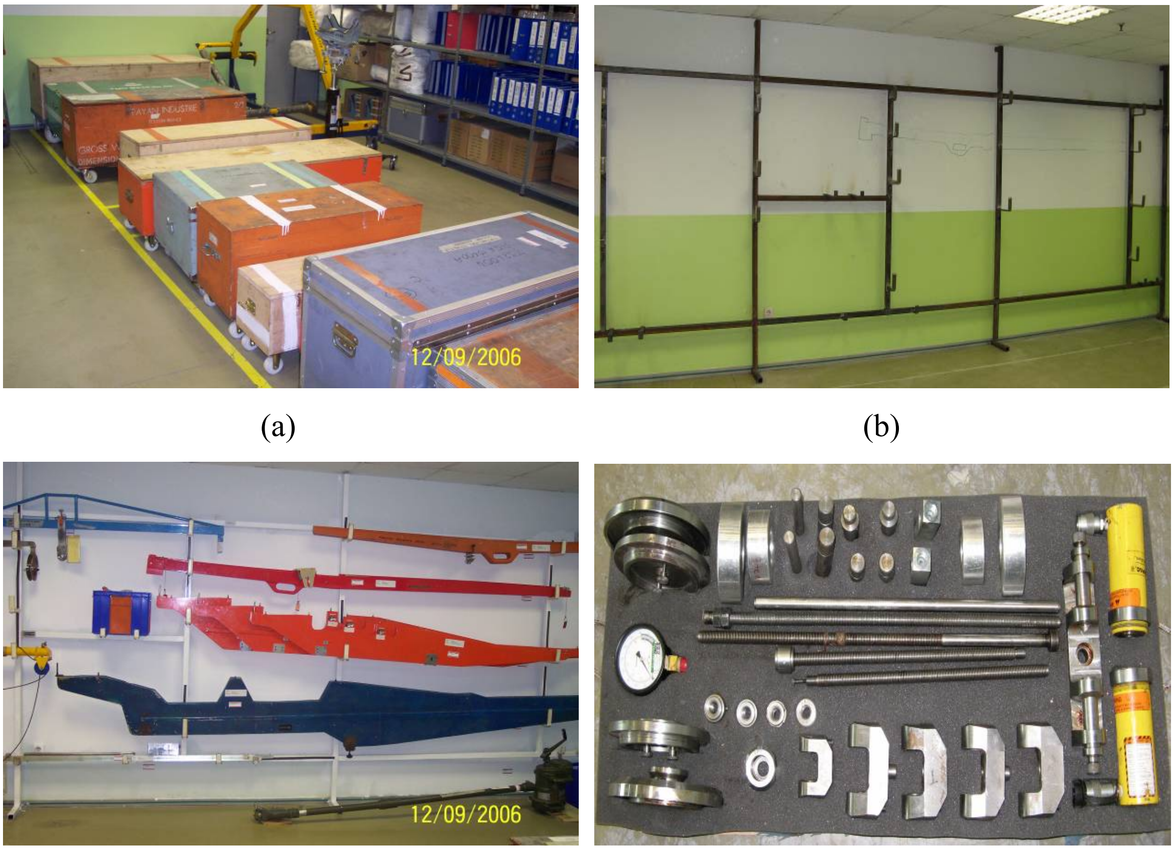
Results

Below are the results of the workshop:

- The area was organized by determining a specific place for each tool; color coding, labeling and shadowing them.
- It is now much easier for technicians to find, reach and take the necessary tools for their tasks.
- As it can be seen in the target sheet in Figure 5.14, safety and ergonomics problems related with the area were reduced from four to one, meaning a 75 per cent improvement. Below are the closed items related with safety and ergonomics:

- Building proper carts for tools, in order to make sure that each tool is stored safely and in good condition
- Putting wheels under each cart in order to make transportation easier (Figure 5.13.a)
- Removing light tools from crates and placing them on the hanging system on the wall, in order to provide an ergonomic reach for these tools (Figure 5.13.c)

The only open item related with ergonomics is making handles for crates with wheels, in order to prevent technician from bending while carrying the crate. This item could not be completed during the workshop week.



(a) (b)

(c) (d)

Figure 5.13. After cleaning the area, a specific place was determined for each tool and all of them were labeled, shadowed and color-coded. Carts with wheels (a). Hanging system (b). Tools hanged on the wall (c). A tool kit (d).

AIW Progress / Results Report

Work Area: Tool Shop Dates: 12/16.06.2006

Team #: 5S lean team Takt time:

Project description (part numbers / processes):

Metrics *1) Select one or more of the following metrics; 2) Track daily results; 3) record percentage improvement at the end of the workshop.*	Start *Actual before AIW*	Target *Expected Results*	Daily Progress Toward Target 1	2	3	4	5	% Change *(Start-Day5) ÷ Start x 100*	Future Goal / Comments
Physical components targeted during AIW									
Safety/Ergonomics (issues)	4	0	4	4	2	1	1	%75	
People Travel (feet)									
Product Travel (feet)									
Space (square feet)	65m²	50m²	60m²	60m²	56m²	48m²	48m²	%26	
Manufacturing components targeted during AIW									
Lead Time (days)									
Cycle Time (minutes)									
Set-up Time (minutes)									
Quality (defects)									
Process efficiency components targeted during AIW									
Productivity (labor hours per unit)									
Volume (units per week)									
Inventory (items)									
Crew size (number)									

Remarks:

Figure 5.14. Target sheet for tool shop 5S workshop

- Large tools section of the tool shop, which is the focus of this workshop, used to consume 65 m^2 floor space. After removing unnecessary items from the area, building a hanging system on the wall and removing light tools from the crates and hanging them on the wall, it was reduced to 48 m^2, meaning a gain of 17 m^2 and an improvement of 26 per cent (Figure 5.14).

5.1.4. Seat Shop 5S

Overview

Another 5S workshop was conducted in the seat shop. This shop is responsible for the maintenance of aircraft seats, trays and safety belts. When an aircraft is taken inside the hangar for heavy maintenance, seats are almost the first parts taken out and the last parts installed, in order to provide the necessary space for accessing the other areas of the aircraft cabin. Removed seats are transported to the seat shop with a truck.

Problem Definition and Motivation

Problems with the initial state:

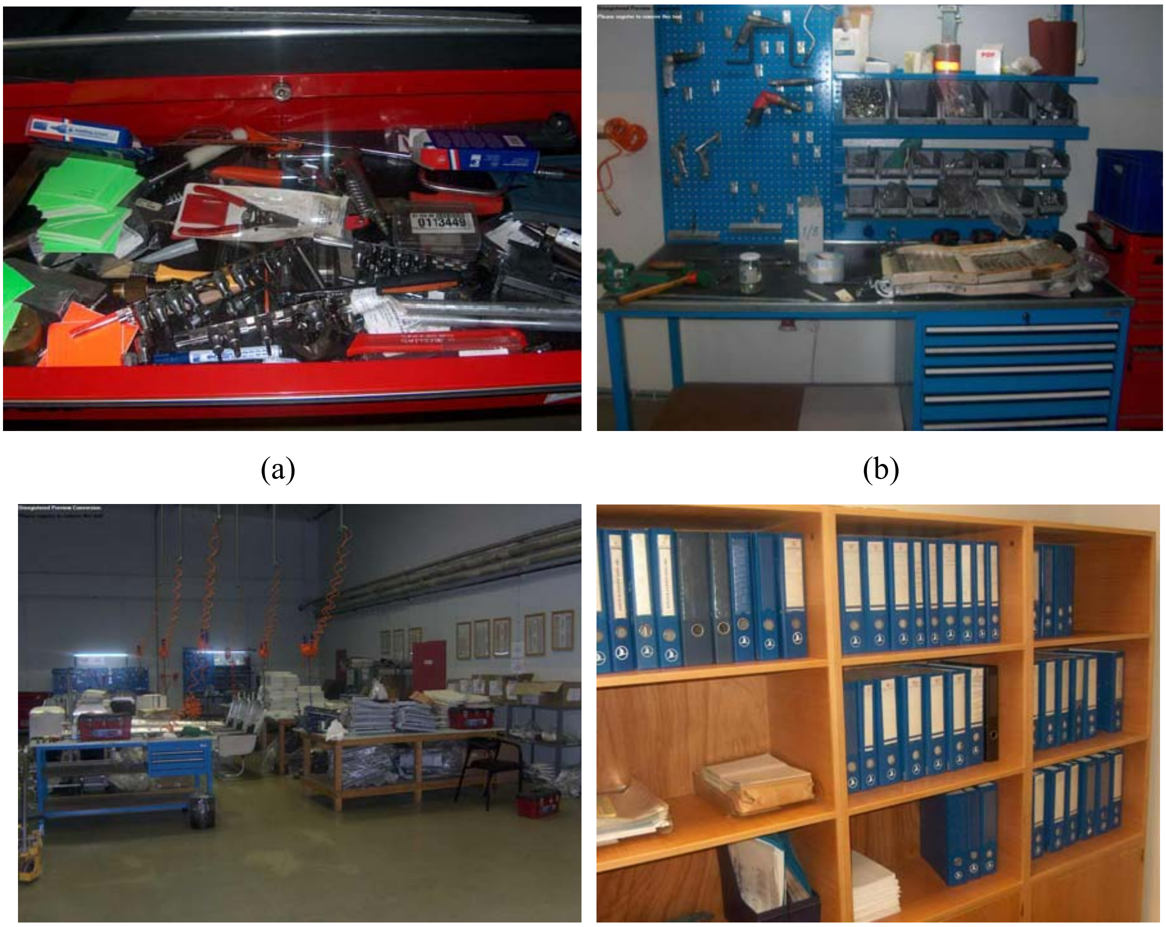
- An aircraft's full set of seats could not fit into the shop. So, they had to leave some of the seats in the hangar or put them into the training room. This situation was creating problems while keeping track of nine or ten aircrafts' seats at the same time.
- There was not any visual control for finding the necessary tools for doing a task, monitoring the progress of each aircraft's seats or the correct places for workbenches and tool carts.
- Although the seat shop needs additional space, there were unused items in the area, for example, serviceable parts that must be sent to the main depot and a cabinet full of old documents.
- The shop was very disorganized and it was very time consuming to find the necessary tools or parts to do a task.

It was very clear that before analyzing the seat maintenance process, the area needed a 5S workshop in order to provide a clean, organized and efficient workplace. Initial state photos of the seat shop can be seen in Figure 5.15.

Deliverables

As it can be seen in the charter document in Figure 5.16, the deliverables of the workshop were:

- Removing all unnecessary items from the area in order to gain space
- Gaining space so that a full set of seats can fit into the shop
- Making everything visual by labeling, color coding and shadowing, in order to reduce the time needed for finding a necessary item and make it easier to detect problems
- Changing the layout of the shop, in order to improve the flow of the seat maintenance process



(a) (b)

(c) (d)

Figure 5.15. Initial photos of the seat shop before 5S. A drawer of the tool cart (a). A workbench (b). General view of the seat shop (c). Documents (d).

Sorting and Simplifying

First of all, the team determined all the unnecessary items in the area. Then, an auction was held to clarify what is needed and what is not. The unnecessary items were removed from the area and a quarantine area was defined for the items that were not decided as necessary or unnecessary. Then, the team started to think about the best layout for the shop, which would support flow.

TÜRK HAVA YOLLARI TEKNIK A.Ş.

İŞ GELİŞTİRME MÜDÜRLÜĞÜ
YALIN ATÖLYE ÇALIŞMASI ARAÇLARI

WS NO: ~~0611~~/ 0702

ANA SÖZLEŞME DÖKÜMANI-~~0611~~ 0702

İŞLEM TANIMI/ DESCRIPTION OF TASK	5S Workshop - Seat Shop
KAPSAM / SCOPE	The scope of the workshop is to 5S the seat shop
SINIRLAR / BOUNDARIES	ALL AREA OF SEAT SHOP from incoming to outgoing including office and break areas
AMAÇLAR / DELIVERABLES	• Touch every single item (including desks and tables and obsolete/excess inventory) and identify necessary or not - hold auction and remove unnecessary - send things back to store or try to sell or throw out • Determine min max levels with re-order kanban cards for perishable supplies • Clean, paint walls and floors, tape locations on floor, knock down walls if necessary etc. • Label shelves, binders, cabinets, make signs etc. • Create inventory lists • Have team come up with best layout and rearrange work area to support flow • Point of Use Tools - foam shadowing • Take before and after photos • Draw before and after layout of area • Have fun!
EKİP LİDERİ / TEAM LEADER	İSMAİL CEM SÖNMEZ (BUSINESS DEVELOPMENT MANAGEMENT - ENGINEER)
EKİP ÜYELERİ / TEAM MEMBERS	• CİHAN AÇIKKOLLU (BUSINESS DEVELOPMENT MANAGEMENT - ENGINEER) • TURHAN EREN (SEAT SHOP - HEAD TECHNICIAN) • HAKAN KURT (SEAT SHOP - TECHNICIAN) • EMRAH YENER (SEAT SHOP - TECHNICIAN) • ÖZER TEZİŞÇİ (SEAT SHOP - TECHNICIAN)
ONAY TARİHİ / PREPARATION DATE	13 OCTOBER 2006 Workshop date: February 12th - 16th, 2007

LİDERLİK ONAYI / LEADERSHIP APPROVAL:

MEHMET ŞENTÜRK	NACİ YÜCEL	MEHMET TİLLA
SEAT Shop Chief	CABIN Interior Mng.	Bussiness Development Mng.

SAYFA 1/1

Figure 5.16. Charter document for seat shop 5S workshop

Standardization and Improvements

Here are the improvement items the team came up with and completed during the workshop:

- Making the part boxes standard and labeling them; so that every single item has a specific place
- Taping floor in order to show the flow of seats during maintenance and correct places for workbenches and tool carts (Figure 5.17.c)
- Sending serviceable parts to the depot and removing the tables used for storing these parts. This improvement item provided the most space for the shop.
- Labeling all the tools and parts, so that everything is very visual and found easily (Figures 5.17.a and 5.17.d)
- Preparing a visibility board showing the workload of the shop, in order to monitor the seats of all aircrafts in maintenance (Table 5.3).
- Buying 6 low stools with wheels for ergonomic work
- Organizing and labeling documents (Figure 5.17.d)

Table 5.3. Visibility board for the seat shop

A/C	Fleet	Maint. Code	# of Seats	# Completed	per cent Completed	Date Started	Expected Comp. Date
TC-JLN	A319	C5	126	80	.63	24.07.2007	26.07.2007
...	...	...	...	...	...	...	...

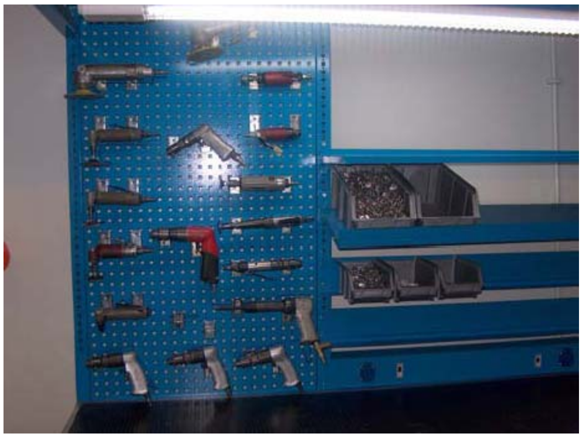
Results

Below are the results of the workshop:

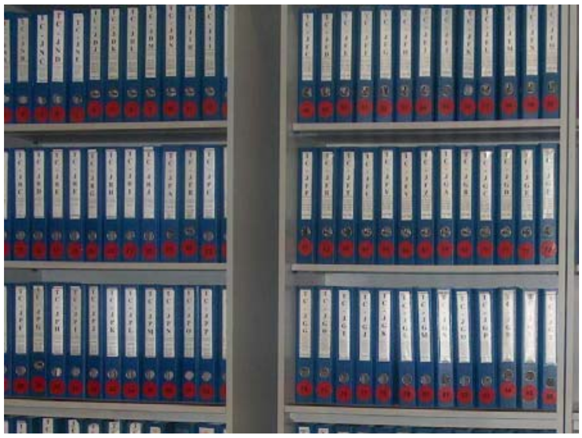
- A specific place was determined for all the tools, parts, workbenches, etc. and labeling, color coding and shadowing were applied for everything, in order to provide an organized, efficient and visual workplace
- It is now much easier for technicians to find the necessary tools or parts for their tasks.
- After all of the kaizen items were completed, approximately 20 m^2 free space was gained, which was enough for the initial aim of the workshop. Now, a full set of an aircraft's seats can fit into the shop, which makes it much easier to track the seats of 9 or 10 different aircrafts and reduces the time spent for correcting mistakes and searching.

"By shadowing and labeling every tool in the shop, we are now able to recognize misplaced or lost items easily. At the same time, now we are able to find whatever we need for our tasks almost immediately." says one of the technicians, who is also the 5S responsible of the seat shop. He also adds that "By labeling and organizing the files and documents, anyone is able to find what s/he needs even though the related person is not there at that moment."

What the technicians, the actual owners of the shop and processes, think and feel about 5S workshop's can be understood from the words of one of the technicians: "Now, we do not look for things and get tired unnecessarily and do not face accident risks. We now work more productively. At first, it was hard for us to change our old habits and adapt the new situation, but now it is easier and it became our routine. This could not be achieved without teamwork."

(a) (b)

(c) (d)

Figure 5.17. Photos of the seat shop after 5S. The same drawer of the tool cart after 5S (a). The same workbench after 5S (b). General view of the seat shop after 5S (c). Documents after 5S (d).

5.2. Accelerated Improvement Workshops (AIWs)

5.2.1. Methodology

Value Stream Mapping helped us see the whole C-Check package process from a global view. It became possible to see the wastes and bottlenecks and produce solutions to make the value flow continuously throughout the process. On the other hand, 5S workshops provided a clean and organized workplace where there is not any unnecessary item, everything has a specific place labeled and shadowed, so that it can be found immediately when needed. Also, problems and abnormalities can be spotted immediately before creating more serious problems. Accelerated Improvement Workshops (AIWs) are more specific workshops aiming to improve a narrower process thoroughly in one week. Two AIWs will be presented in this section after explaining the methodology.

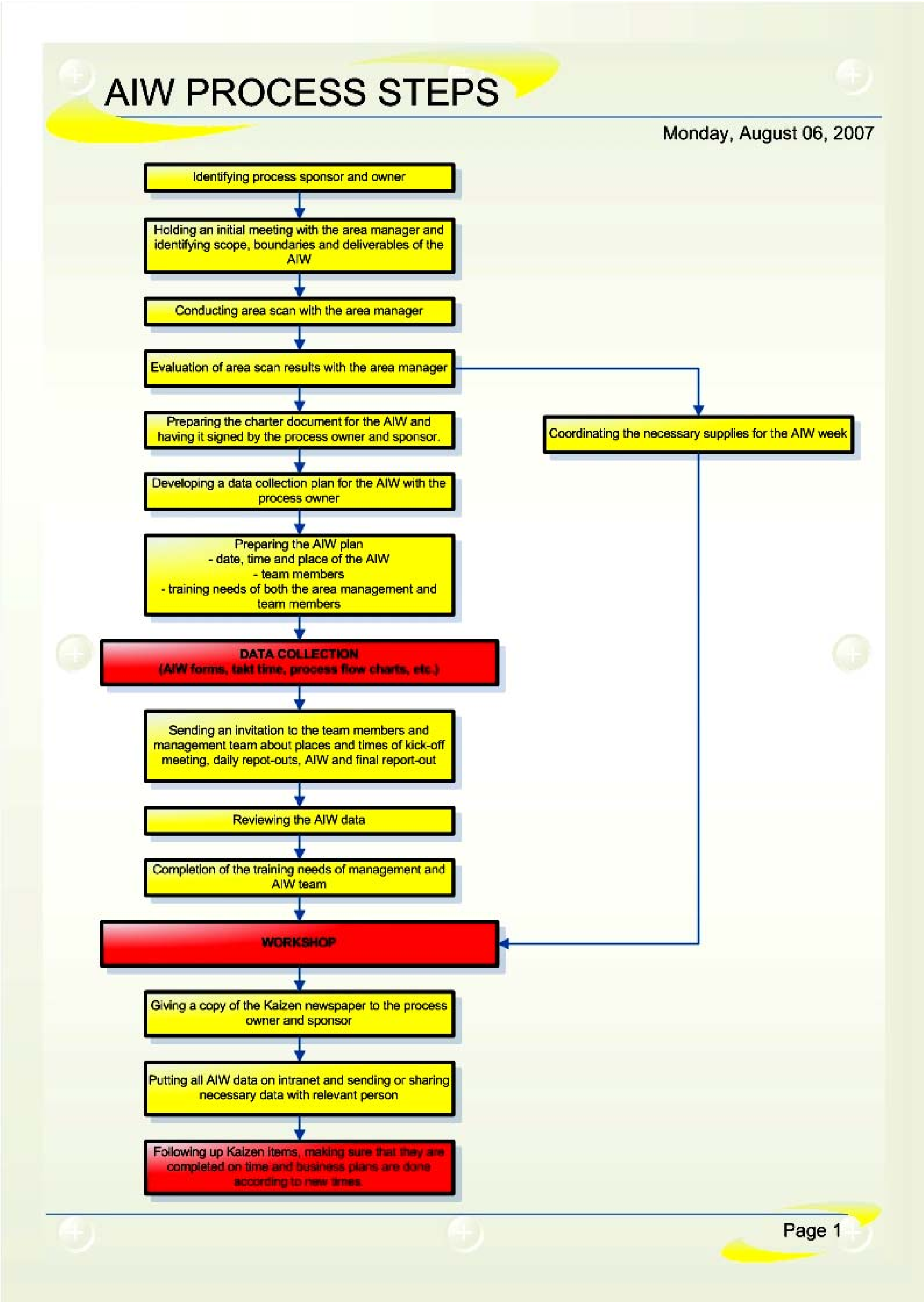


Figure 5.18. AIW process map

As it can be seen in Figure 5.18, an AIW process starts with identifying process sponsor and owner. Process sponsor is usually a second level manager and process owner is usually a first level manager, namely shop chief or chief engineer in Turkish Technic. An initial meeting is held with process sponsor and owner in order to identify scope, boundaries and deliverables of the AIW.

Next, a process walk is conducted together in order to gain the first impressions about the process and collect suggestions from the employees. Boeing's Area Scan Checklist (Figures 5.19 and 5.20) is filled with the process sponsor and owner. This checklist is an efficient tool to understand the process, culture and willingness of the area for improvement and their readiness for the AIW in terms of base tasks such as 5S and visual control. It also signals the improvement potential from an AIW and facilitates employee and management buy-in.

From the checklist (Figure 5.19), it can be observed that the engine shop has a high spirit of improvement, whereas a lot of non-value-added activities like waiting and walking can be observed easily. Engine modules are generally big and circular parts, which makes any kind of movement, whether parts, components, tools or whole module, wasteful. Modules are assembled one at a time, since they have relatively long cycle times. There are relatively high number of spare parts, components and engine. This is mostly because of long cycle time of engine overhaul and the variability of the processes. Shop has a moderate level of organization thanks to previous 5S efforts. On the other hand, there are not enough visual control elements to support these efforts. Also, workload variability is rather high, which necessitates heijunka (workload leveling) efforts on the pacemaker final assembly process.

After evaluating the area scan checklist, charter document is prepared by the AIW leader and signed by the shop chief, shop manager and process improvement manager, which means that the sponsor and the owner of the process accept all of the kaizen items that will be produced by the AIW team and give full support to remove any possible road blocks to complete these kaizen items. Actually, process owners and sponsors should participate in the AIW as team members in order to show their support. This is very important for the message given to the AIW team and to everyone in the shop and much more effective than just signing the charter document and attending the daily report outs.

AREA SCAN CHECKLIST (PAGE 1)				
	-	0	+	Comments
1. Spirit of Improvement				
A. Enthusiasm/commitment of management?	Low		High	
• Reasons for interest in rapid improvement				
B. How will management participate?	Low		High	
• Level of active involvement planned				
C. Expectations for Improvement?	Low		High	
• Low or high aspirations				
D. Visual display of improvement activity?	Low		High	
• Evidence of goals and progress				
• Improvement teams active				
2. Process/Product Orientation				
A. Does area include a product?	No		Yes	
• Different processes included?				
B. Is the area layout by function?	No		Yes	
C. Extent product flow is possible	Low		High	
• Estimate opportunity for improvement				
D. Processing time/throughput time ratio (VA%)	Low		High	
E. Inventory levels	Low		High	
3. Equipment				
A. Actual processing mostly one-unit	No		Yes	
• Batch not necessary for process				
B. Easy to move	No		Yes	
• Size, foundations, utilities, complexity				
C. Any unique machines that may be a bottleneck?	No		Yes	
D. Any areas shared with other operations?	No		Yes	
4. Workplace Organization				
A. Much sorting needed?	No		Yes	
B. Workplace organization level	Low		High	
C. Safety hazards, mess?	No		Yes	

Figure 5.19. Area scan checklist for HPC forward case AIW (page 1/2)

AREA SCAN CHECKLIST (PAGE 2)				
	-	0	+	Comments
5. Visual Control				
A. Is schedule status apparent?	No		Yes	
B. Are work methods visual?	No		Yes	
C. Are location for tools and work apparent?	No		Yes	
D. Are measures visually displayed?	No		Yes	
6. Demand -- Work Statement				
A. Does area include a product?	No		Yes	
B. Is the area layout by function?	No		Yes	
C. Extent product flow is possible	No		Yes	
7. Culture				
A. Past improvement experiences positive?	No		Yes	
• Management view / employee view				
B. Morale level	Low		High	
• Reasons				
C. Teamwork	Low		High	
• Current level of cooperation within/between levels				
D. Previous education in process improvement and cycle time reduction?	Low		High	
E. Flexibility of workforce?	Low		High	
F. Union relationship is positive?	No		Yes	
• Problems / Anticipated issues				
G. Extent to which previous improvements involved employees.	Low		High	
H. Sense of urgency for improvement?	Low		High	

Figure 5.20. Area scan checklist for HPC forward case AIW (page 2/2)

At the same time, AIW leader starts to coordinate the necessary supplies and makes sure that they are ready for the AIW week. Those supplies include daily and final report out rooms, process maps, area layout, easel chart, post-its, empty AIW forms, scissors, tape, marker, manuals and procedures about the process and the area, etc.

Next, team members are determined by the area leaders and the AIW leader. When selecting team members, they should take into consideration to represent every phase of the process and they should also include team members from the upstream, downstream and support processes in order to create flow between processes. Performers of the task are maybe the most important team members, since they know the process better than anybody else in the team and they have the highest potential to produce kaizen items if coached and motivated correctly. If the operators lack lean training or have not participated in a kaizen event before, they might be disturbed by the other team members questioning the process and take a defensive position which kills the momentum of the AIW and minimizes the most important potential for producing kaizen items. Thus, if two operators will participate in the AIW, one might be selected from employees with kaizen event experience and the other without kaizen event experience. This both spreads kaizen experience in the area and at the same time maintains the success of AIW.

Furthermore, all team members are supposed to participate full time in the data collection and AIW without interruptions for their daily tasks. This means that their daily activities should be covered by back filling their tasks during the data collection and AIW. Also, some on-call team members can participate in the AIW if needed. Those on-call team members might be from support departments such as IT or they might have special skills needed only for a short time during the AIW.

Next, a data collection plan is developed with the area leaders. Data collection is done a couple of weeks before the AIW, in order to measure the current state of the process in terms of

- cycle time, lead time, set-up time,
- safety, ergonomics and quality issues,
- people and product travel,
- space used,

- productivity,
- and inventory.

Data collection provides a reference point for comparison after improvements. It has constraints such as product, process and team member availability. For example, it has to be scheduled according to a specific type of engine module or according to the availability of team members. A data collection plan specifies when and where the data will be collected and who will collect the data.

After data collection plan is determined, an invitation e-mail is sent to the team members and their managers about the plan, kick-off, daily and final report outs for the AIW. This invitation e-mail should be sent as early as possible, so that schedule changes and back filling can be arranged on time.

Training needs of the team members and area leaders are determined and lean training is scheduled for them before data collection, if needed.

Data collection includes filling Boeing's four main forms:

- Time Observation Sheet: This is the main form, from which other three forms are derived. In this form, process steps are timed. One form is filled for each operator. An example can be seen in Figure 5.23.
- Standard Work Combination Sheet: In this form, process steps are simply laid on to the time axis as a gannt chart. Also, different types of process steps, such as walk, manual, auto, wait are color-coded, so that it is easier to see and attack wastes inside the process. An example can be seen in Figure 5.25.
- Standard Work Sheet: This is the form where all travel of the operator can be seen while doing his/her tasks. Also total walking distance of the operator is calculated in this form. An example can be seen in Figure 5.26.
- Percent Load Chart: In this form, a bar chart shows the percentages of times for
    - value added
    - non value added but necessary
    - non value added and unnecessary tasks

    An example can be seen in Figure 5.27.

After data collection, all trainings of the area management and AIW team members are completed before the AIW week. The aim of the training is to make sure that everybody knows lean principles, how to use forms, why it is necessary to do an AIW in their work area and what their specific roles and responsibilities will be in order to achieve the success of the AIW.

During the AIW week, every team member is required to think outside the box and come up with improvement ideas, no matter how nonsense or impossible they seem at the first moment. In order to encourage team members to think outside the box, a simple game called nine-dot can be played in the training. This is a simple but effective game which shows the importance and power of thinking outside the box. In this game, there are nine dots put into a square shape (Figure 5.21.a) and team members are requested to connect them with four straight lines without removing their hands from the paper. Most team members get stuck in this square shape and search for the answer inside the box whereas the solution is outside the box (Figure 5.21.b).

Team was supposed to simulate every possible way of doing a task and measure them in order to find the best possible alternative. Kaizen items are followed by kaizen newspaper form, on which every item has a description of the problem, a solution to that problem, a responsible (sometimes two or more) and an expected completion date (ECD). Team should try to complete as much item as possible during the AIW. For the items not completed during the AIW week, process improvement department conducts periodic kaizen walks to follow up these items. At the end of each day, all AIW teams conduct a report out and attend the report outs of the other AIW teams, where every team explains their progress so far, their plan for the next day and kaizen items being worked on. Area management and other employees working in the area attend these daily report outs, so that they know the aim of the AIW and the kaizen items to improve the process. This facilitates the buy-in of everyone in the area.

At the last day of the AIW, a final report out is conducted, to which every employee in the company is invited. In the final report out, team informs the audience about the initial goal of the AIW and actual results. Here, all the AIW forms are compared with the

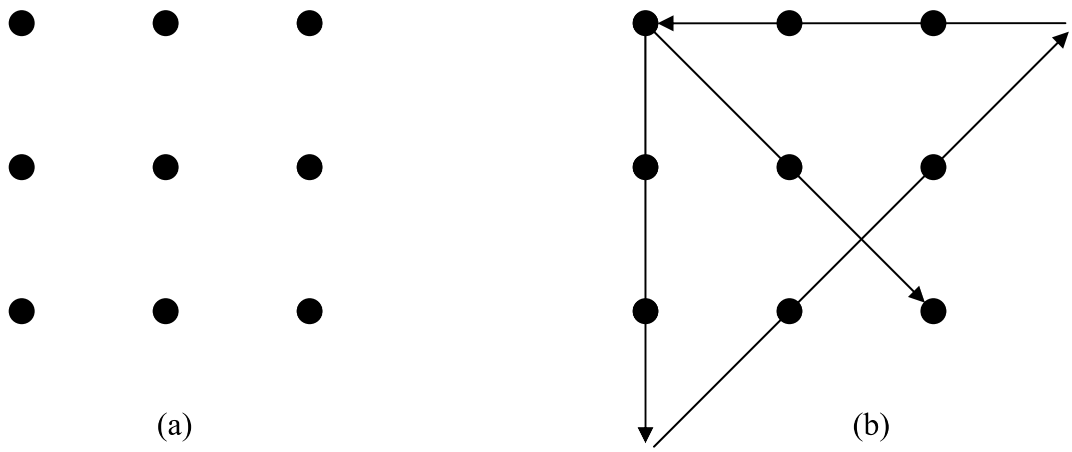


Figure 5.21. Nine-dot example (a) and the solution (b)

forms prior to improvements. Important kaizen items are described and if possible, before and after improvement situations of the problems are demonstrated.

After the AIW, process improvement department ensures that all the improvements made during the AIW are maintained in the area and business plans are done according to new cycle time of the process. They also periodically follow up kaizen items not completed during the AIW week.

5.2.2. HPC Forward Case Assembly AIW

High Pressure Combustor (HPC) Case assembly of CFM56-3C engines was chosen as one of the first AIWs in Turkish Technic's engine overhaul shop.

<u>Deliverables</u>

As it can be seen in the charter document (Figure 5.22), the deliverables of the AIW were:

- technician travel reduction
- reduction of the cycle time of the assembly
- productivity increase by eliminating non-value added process steps
- providing point of use tools for the technician

Data Collection

AIW team consisted of,

- two engineers from process improvement department (one is the AIW leader and the other is the co-leader),
- one engineer and two technicians from the engine shop,
- one engineer from the engine shop ppc. Charter document was signed by the shop chief, shop manager and process improvement manager, which shows their support to the AIW.

First of all, team started to measure the current state of the process in order to provide a base for comparison after improvements. HPC Fwd. Case is composed of two case halves and assembly is done by two technicians. Each technician works on one half, so they were observed separately. A time analysis was conducted using time observation sheets, in which process steps were measured as detailed as possible (Figure 5.23). Assembly took 9 hours and 55 minutes (Figure 5.24).

CHARTER DOCUMENT - 0619
AUGUST 06

DESCRIPTION OF TASK	HPC FORWARD CASE ASSEMBLY (CFM56-3C)
SCOPE	HPC FORWARD CASE ASSEMBLY (CFM56-3C)
BOUNDARIES	FROM : ASSEMBLY OF HPC FWD. CASE TO : COMPLETION OF THE ASSEMBLY
DELIVERABLES	• CYCLE TIME REDUCTION • PEOPLE TRAVEL REDUCTION • PRODUCTIVITY INCREASE • POINT OF USE TOOLS (TOOL KIT PREPERATION)
TEAM LEADER	CİHAN AÇIKKOLLU (BUSINESS DEVELOPMENT MANAGEMENT - ENGINEER)
TEAM MEMBERS	• İSMAİL CEM SÖNMEZ (BUSINESS DEVELOPMENT MANAGEMENT - ENGINEER) • MURAT AYGAN (ENGINE OVERHAUL SHOP - ENGINEER) • SERHAT SALİH İLHAN (OVERHAUL SHOPS DIRECTORATE – SHOP ENGINEER) • ERCAN BÜYÜKSAĞLAM (ENGINE OVERHAUL SHOP - TECHNICIAN) • VEYSEL KOCA (ENGINE OVERHAUL SHOP - TECHNICIAN)
PREPARATION DATE	10 JULY 2006

LEADERSHIP APPROVAL:

AYHAN GÜCENMEZ
ENGINE O/H Shop Chief

MÜJDAT ULUDAĞ
ENGINE O/H Shop Mng.

MEHMET TİLLA
Bussiness Development Mng.

Figure 5.22. Charter document for the HPC forward case assembly AIW

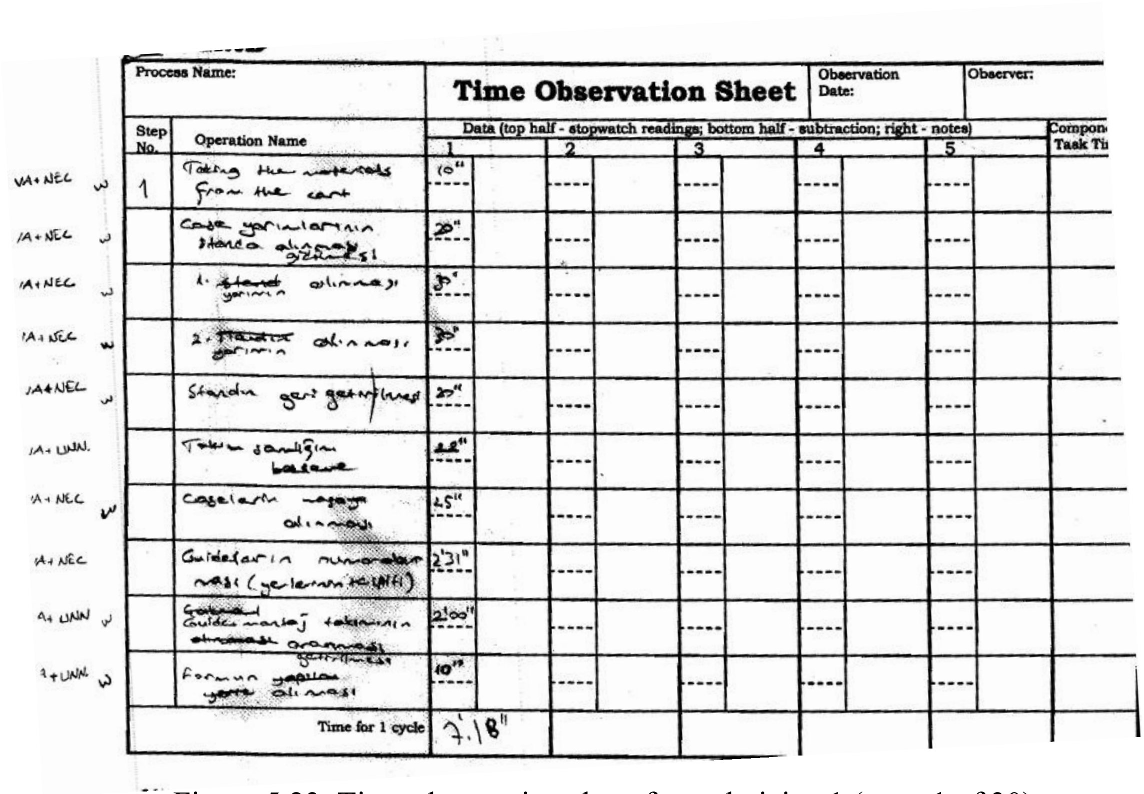
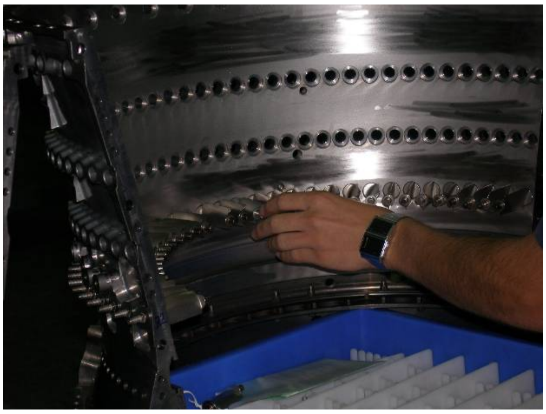
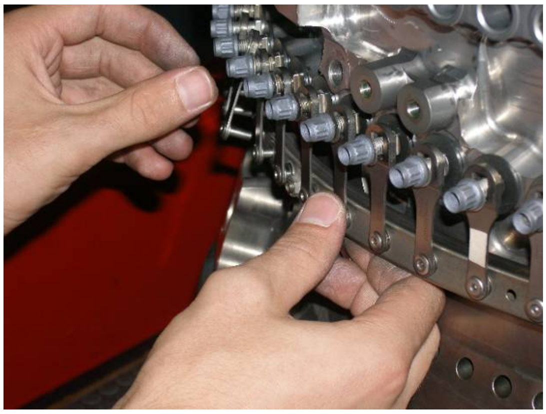


Figure 5.23. Time observation sheet for technician 1 (page 1 of 30).

Secondly, process steps were laid on to time axis by using Boeing's Standard Work Combination Sheet (Figure 5.25). In this sheet, manual, automatic, walking and waiting steps were color-coded in order to make the process more visual and find wastes more easily.

Standard work sheet, also called spaghetti chart, was used in order to see the technician travel. As it can be seen in Figure 5.26, total travel distance for technician one is 2,473 meters. The technician went to the tool shop 30 times, to the other stand 33 times and to the parts cart 28 times during the process, which is a signal of non-dedicated work benches and disorganization of the work area. The technician also went to work table, his personal tool box, grinding machine in the machine shop, photocopy machine, shop ppc (production planning and control), tool shelf, computer and shop depot several times. When the spaghetti chart was shown to the operator, he could not believe that he walked that much during the process. From that point, he produced many kaizen items to reduce his travel distance.

(a) (b)


(c) (d)

Figure 5.24. Installation of veins (a), actuator ring (b), shrouds (c) and serviceable HPC forward case (d).

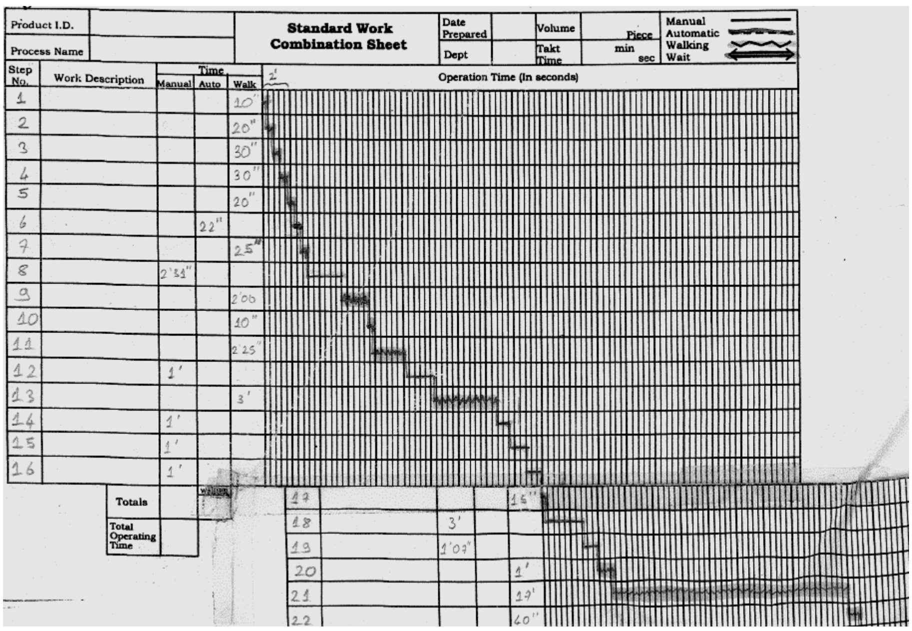


Figure 5.25. The first page of standard work combination sheet for technician one

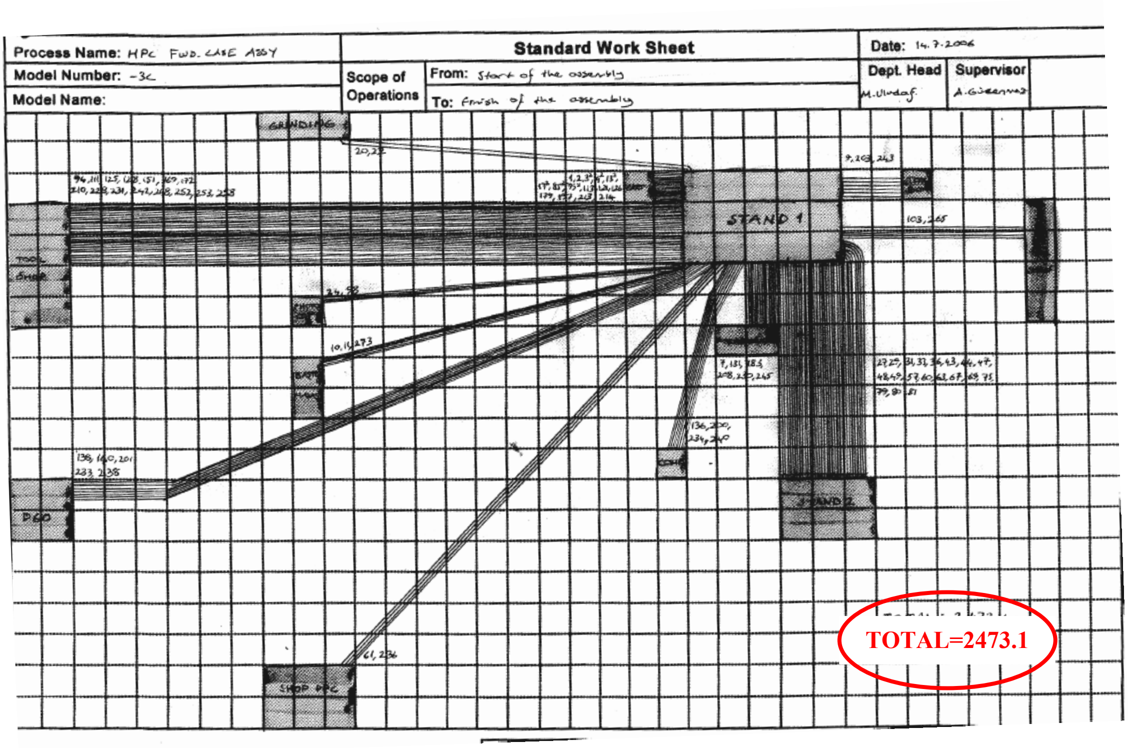


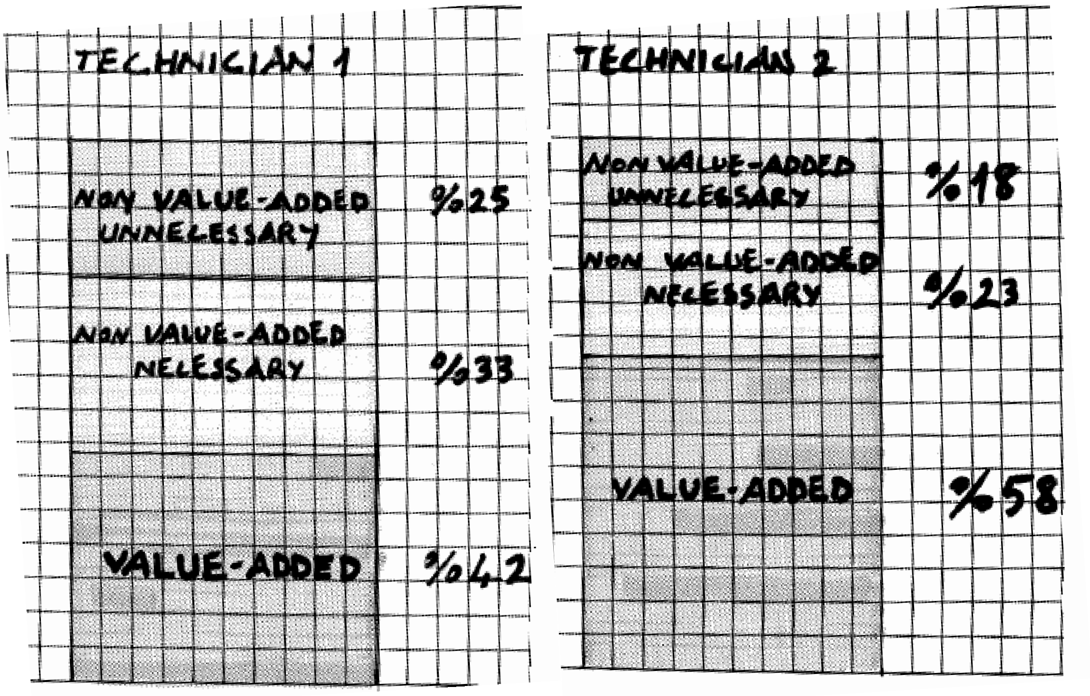
Figure 5.26. Standard work sheet (spaghetti chart) for technician one (before AIW)

Next, the team analyzed the time observation sheet and identified each step as

- value-added,
- non value-added but necessary
- or non-value added and unnecessary.

When deciding whether a process step is value added or not and necessary or not, team should think about the downstream process in terms of value. As explained in more detail in section 2.3.1, any activity which does not add value for the customer is waste, such as filling necessary forms, looking at manuals, every kind of walking, waiting, rework, quality check, etc. Some kind of wastes can be eliminated immediately during the AIW, such as building a tool kit for the task, so that the technician does not walk much to take or find his tools. On the other hand, some kind of wastes can not be eliminated in the short term. These might be wastes related with suppliers, information technology, facilities, procedures, authorities, etc. However, this does not mean that we omit these wastes. Solutions to these problems must be determined, a responsible and an expected completion date must be assigned to these kaizen items and they must be followed up periodically.

The team sorted process steps into three categories and summed up their times. As it can be seen in Figure 5.27.a, value-added process steps accounted for only 42 per cent of the total cycle time for technician one. These process steps are just what the downstream process wants such as installing a shroud on the case or screwing a bolt. 33 per cent of the total cycle time is spent for non-value-added but necessary process steps, such as filling necessary forms or looking up reference documents, for example the engine manual. What is most striking is that 25 per cent of technician's time is spent on non-value-added and unnecessary activities such as walking, waiting, rework, etc. The situation was better for technician 2 (Figure 5.27.b). Value-added process steps accounted for 58 per cent, whereas non-value-added but necessary steps were 23 per cent and non-value-added and unnecessary steps were 18 per cent.



(a) (b)

Figure 5.27. Percent load charts for technician one (a) and technician two (b) before AIW

Improvements

Both during data collection and AIW, team produced 13 kaizen items and 11 of them were completed during the AIW week. Table 5.4 shows the kaizen items of this AIW:

Table 5.4. Kaizen items for HPC forward case assembly

#	Problem Definition	Solution	Resp.	ECD	% Comp.
1	Although 84 bushings are used for each stage, they come in packages of five. It is very time consuming for the technician to take them out of packages.	Improving parts presentation for the assembly. Making sure that bushings come in packages of 84 (Figure 5.29.f).	S.S.İ.	**16.08.2006**	**100%**
2	Vanes on seals come without being grinded, so technician has to grind them before installing.	Improving parts presentation for the assembly. Machine shop will grind seals immediately after installing them on vanes.	M.A., S.S.İ.	**14.11.2006**	**25%**
3	Technician can not be sure which consumable part to use at a specific point during assembly and he has to look at the Engine Manual very often and long.	Improving parts presentation for the assembly. Consumable parts will be kitted by ppc[8], according to technician's order of usage (Figure 5.29).	S.S.İ.	**16.08.2006**	**100%**
4	Guides have to be grinded during assembly.	Improving parts presentation for the assembly. Making sure that guides are grinded by the machine shop beforehand.	S.S.İ.	**16.08.2006**	**100%**
5	Actuation ring and bushings of each stage are presented separately and without any order.	Improving parts presentation for the assembly. Each stage's actuation ring and bushings should be kitted and presented in the order of technician's usage. This will eliminate going to the cart for each stage's ring and bushings (Figure 5.29.e).	S.S.İ., M.A.	**16.08.2006**	**100%**
6	There is not a dedicated workbench for HPC Fwd. Case Assembly. This job is done on any empty workbench in the shop.	Preparing a dedicated workbench for HPC Fwd. Case Assembly.	M.A.	**16.08.2006**	**100%**
7	Tools necessary for the assembly are not organized. Technician goes to the tool shop and his personal toolbox very often. Increases technician travel significantly.	Preparing a dedicated toolbox for HPC Fwd. Case assembly and placing it at the dedicated work bench (Figure 5.30).	M.A.	**16.08.2006**	**100%**
8	Technician uses manual hand tool for installing almost 100 bolts and nuts. It is very time consuming and ergonomically unfavorable (Figure 5.28).	Making sure that a battery drill is present on the workbench.	M.U., M.A.	**14.09.2006**	**100%**

[8] Production Planning and Control

9	Technician uses injection syringe for applying RTV chemical. It is not a proper tool for the task.	Making an ergonomic and proper tool for the task.	M.A.	**14.09.2006**	**25%**
10	Swab is placed in a far corner of the shop. It increases technician travel.	Making sure that each workbench has enough swabs.	M.A.	**16.08.2006**	**100%**
11	Since HPC Fwd. Cases are big and circular parts, technician has to walk around them very often in order to install hundreds of bushings, bolts and nuts.	Building a turntable for the HPC Fwd. Case workbench.	M.U.	**15.09.2006**	**100%**
12	Documents needed for assembly stay in the tool shop and each time technician has to take a photocopy of them.	After dedicating a workbench for HPC Fwd. Case assembly, placing necessary documents on this workbench.	M.A.	**15.09.2006**	**100%**
13	Air hose is not ready for use.	Building a hook for the end of hose in order to make sure that it is always ready to be used.	M.A.	**01.09.2006**	**100%**

Kaizen item #8 suggests using electric drill instead of manual hand tool for installing bolts and nuts. Both methods can be seen in Figure 5.28. Surely, electric drill is much more effective and ergonomic.

(a) (b)

Figure 5.28. Installing nuts using manual hand tool (a) and electric drill (b)

Kaizen items #1, 2, 3, 4, 5 are all about parts presentation, which is the responsibility of shop PPC (Production Planning and Control). We should think technicians as surgeons and we must make sure that they do not go look for parts, count them to check if there is missing or look at the manuals for ten minutes to find out which part to use next. Because all of these activities are non-value-added and do not mean anything for the customer. Although, it seems that man-hour gained in the assembly process is shifted to PPC, time needed for parts presentation is significantly lower than time needed on the assembly workbench to make the value flow. Even though these times are equal, an effective parts presentation significantly reduces cycle time, which makes these changes much more than feasible as it will be presented in the target sheet.

Part kits for HPC Forward Case are shown in Figure 5.29. Note that all part kits include their own consumable parts and arranged in the order of technician's usage, since they are designed by the assembly technician and PPC technician together.

Kaizen items # 6, 7, 8 are about tool presentation. In the spaghetti chart in Figure 5.26, it was seen that the first technician walked 2,473 meters to complete his job. Most of the time, he went to the tool shop, tool shelf or his personal tool box to get the necessary tools for his task. All of these process steps are absolutely non-value-added and unnecessary and can be eliminated with an effective tool presentation for the technician. For an effective tool presentation, first of all, a specific workbench must be dedicated to HPC Forward Case assembly. Then, all the necessary tools used during the assembly must be located at this dedicated workbench or at a closest place possible. Tool kit prepared for HPC Forward Case is shown in Figure 5.30.

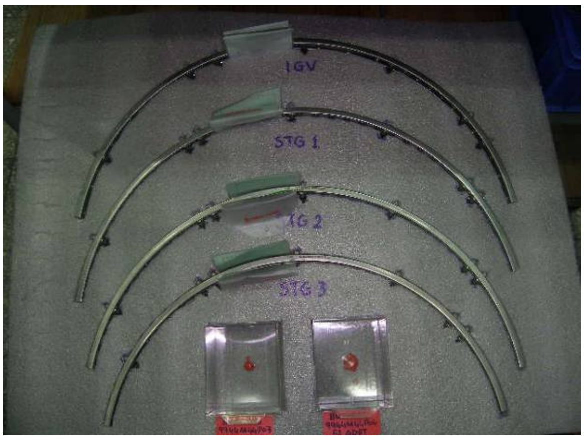
HPC Forward Case is composed of six stages, stages one through five and the IGV stage. There is only one special tool for each stage (Figure 5.31). Technicians used to work on their half cases independently of each other and sometimes they work on the same stage at the same time and wait for this special tool. In order to eliminate this possibility of waiting, now, they work synchronized with a phase difference of one stage between them. For example, first technician starts with the lowest stage, stage five, while second technician with stage four and they go upward.

(a)

(b)

(c)

(d)



(e)

(f)

Figure 5.29. Part presentation kits for connecting lines (a), stage 1, 2, 3 shrouds (b), seal retainers (c), stage 4 and 5 shrouds (d), actuator rings (e) and consumable parts (f)

Figure 5.30. Tool kit for HPC forward case assembly

All kaizen items except #2 and #9 were completed before Wednesday evening. On Thursday morning, the fourth day of the AIW, team started to collect data for the improved process. Since, two technicians work synchronized now, AIW team decided to collect data for only the first technician. All AIW forms were prepared for the improved process in order to compare them with the before-AIW situation.

Figure 5.31. Technician using stage three tool

Results

It is very striking to see that after improvements, technician went to the tool shop only once for a special chemical that must be stored in the refrigerator (Figure 5.32), whereas technician went to the tool shop 30 times before improvements in order to take tools, chemicals and documents. Moreover, he did not need to go to

- his personal tool box or tool shelf, because all necessary tools for assembly were ready in the tool box under the workbench;
- machine shop for grinding, because a small grinding machine is located at the dedicated workbench until kaizen item #2 in Table 5.4 is closed;
- photocopy machine, because all documents needed were ready on the dedicated workbench;
- shop PPC or shop depot, because shadowed and labeled part kits prevented missing or wrong parts.

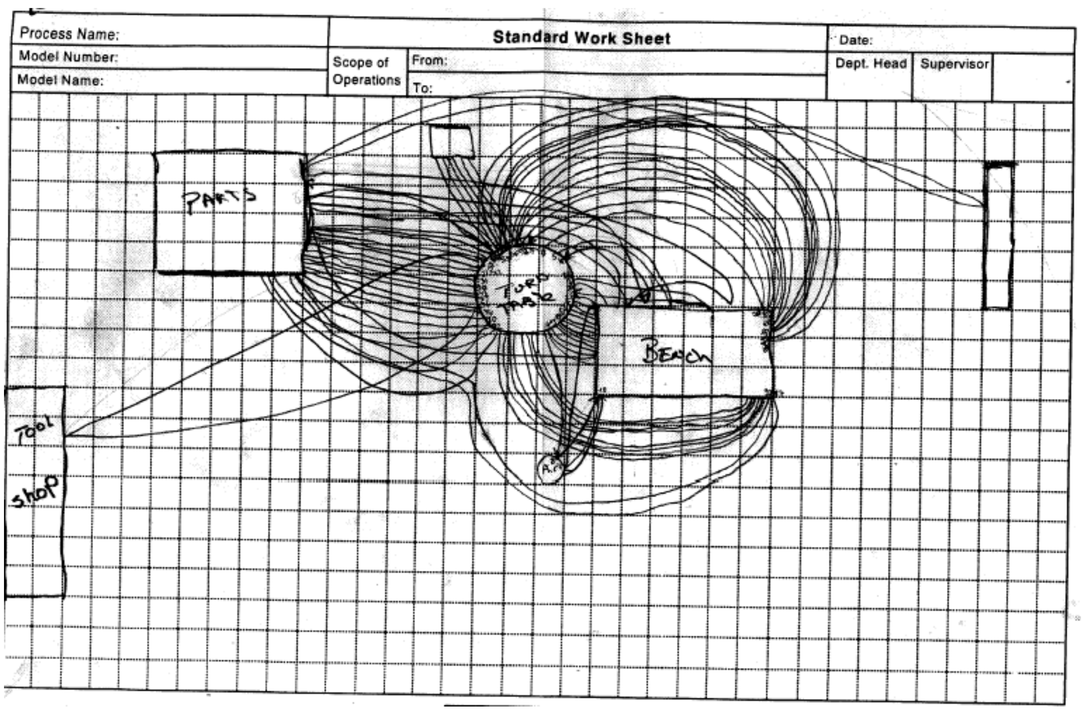


Figure 5.32. Standard work sheet (spaghetti chart) for technician one (after AIW)

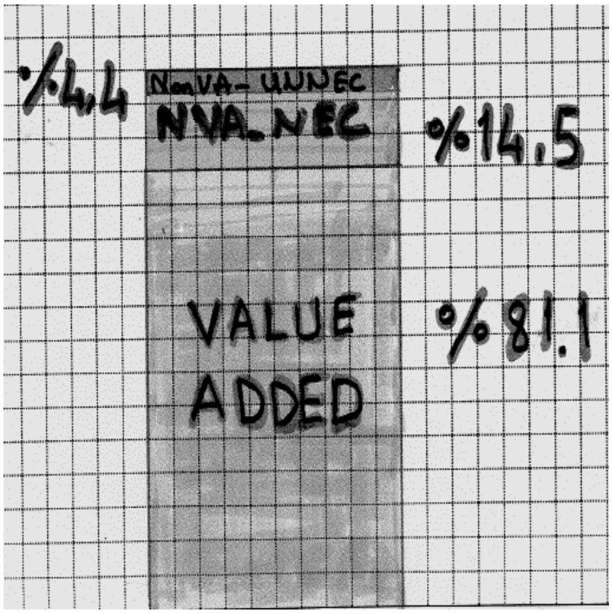
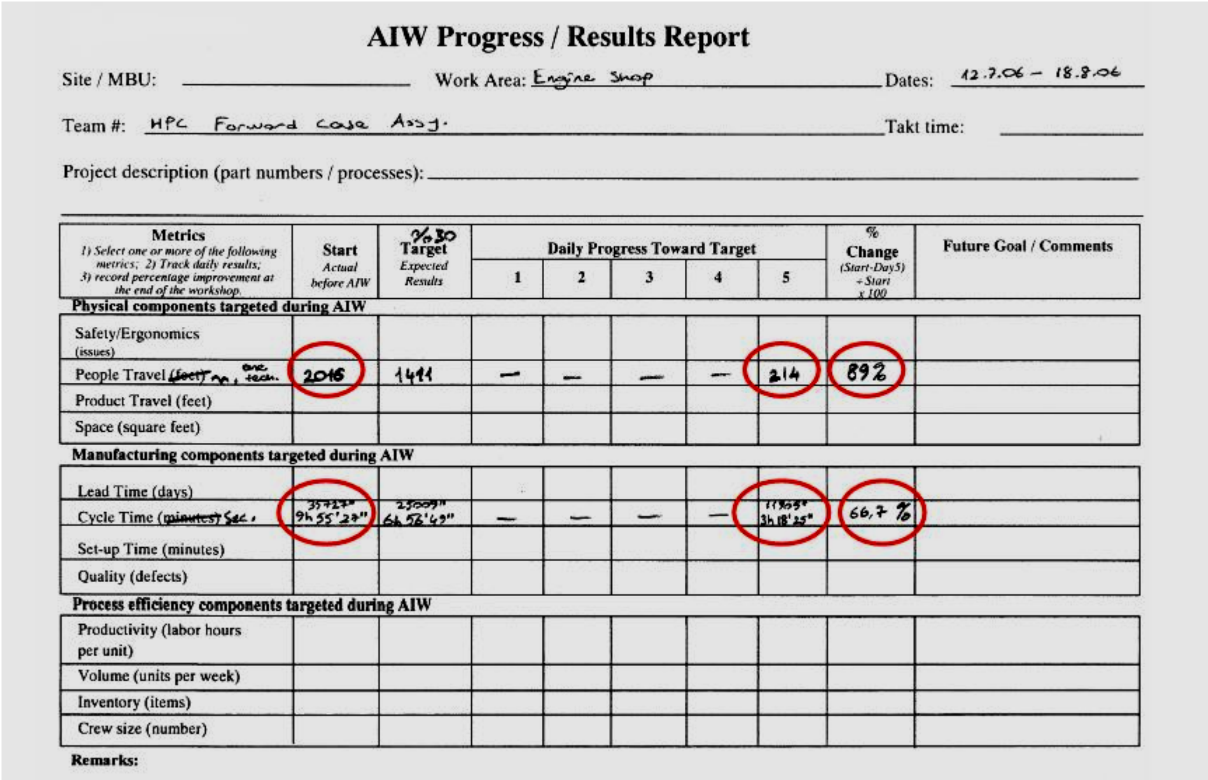


Figure 5.33. Percent load chart for technician one after improvements

Furthermore, if we compare Figure 5.27 with Figure 5.33, after improvements, total time of value-added steps increased from 42 per cent to 81 per cent, while total time of non-value-added and unnecessary steps, such as walking and waiting, decreased from 25 per cent to 4,4 per cent. Total time of non-value added but necessary steps, such as looking at manuals, decreased from 33 per cent to 14½ per cent.

Finally, if we look at the AIW Progress / Results Report (Figure 5.34), which is also another form of Boeing, we can see that average technician travel used to be 2,016 meters. AIW target was to decrease it 30 per cent to 1,411 meters and the result is a significant 89 per cent reduction to only 214 meters. Cycle time of the assembly used to take 9 hours and 55 minutes. AIW target was to reduce it 30 per cent to 6 hours and 56 minutes and the result is a significant 66 per cent reduction to just 3 hours and 18 minutes. Although results are very striking, this is very normal for companies newly starting a lean journey. Most of the improvements are due to low hanging fruits of effective parts and tools presentation and dedicated workbenches.



AIW Progress / Results Report

Site / MBU: ______ Work Area: Engine Shop ______ Dates: 12.7.06 – 18.8.06

Team #: HPC Forward Case Assy. ______ Takt time: ______

Project description (part numbers / processes): ______

Metrics 1) Select one or more of the following metrics; 2) Track daily results; 3) record percentage improvement at the end of the workshop.	Start Actual before AIW	%30 Target Expected Results	Daily Progress Toward Target 1	2	3	4	5	% Change (Start-Day5) ÷ Start x 100	Future Goal / Comments
Physical components targeted during AIW									
Safety/Ergonomics (issues)									
People Travel (feet) m, one tech.	2016	1411	–	–	–	–	214	89%	
Product Travel (feet)									
Space (square feet)									
Manufacturing components targeted during AIW									
Lead Time (days)									
Cycle Time (minutes) sec.	35727" 9h 55' 27"	25009" 6h 56' 49"	–	–	–	–	11905" 3h 18' 25"	66,7 %	
Set-up Time (minutes)									
Quality (defects)									
Process efficiency components targeted during AIW									
Productivity (labor hours per unit)									
Volume (units per week)									
Inventory (items)									
Crew size (number)									

Remarks:

Figure 5.34. AIW progress/results report for HPC forward case assembly

Table 5.5. Results of the AIW

	Before AIW	Target	After AIW	Improvement
Cycle time	9 hours 55 mins	6 hours 57 mins	3 hours 18 mins	67%
Average technician travel	2016 meters	1411 meters	214 meters	89%
Value-added / total cycle time	42%	60%	81%	93%
Non-value-added / total cycle time	58%	40%	19%	67%

5.2.3. HPT Shroud / LPT Nozzle Assembly AIW

HPT Shroud and LPT Nozzle Assembly of CFM56-7B engines is one of the most successful and efficient AIWs in Turkish Technic so far. HPT Shroud and LPT Nozzle modules are assembled separately and then joined together. Scope of the AIW was to observe these two module assembly processes separately. Joining them together was out of scope, since there was not enough time to observe this joining process in the same AIW week. This AIW was one of the most efficient, because in fact two AIWs were conducted in the same week by a relatively small team.

Deliverables

Below are the deliverables of the AIW:

- reducing cycle time and people travel
- increasing productivity
- providing point of use tools by preparing dedicated tool kits
- improving parts presentation by kitting parts in the order of technician's usage.

Data Collection

AIW team consisted of

- one engineer from process improvement department,
- one engineer and one technician from the engine overhaul shop
- and one technician from shop PPC, which is the supplier of module assembly processes.

Charter document was signed by the shop chief, shop manager and business development manager in order to show their support to the AIW (Figure 5.35).

Firstly, current state data was collected by using time observation sheets for both assemblies. First pages of time studies are presented in Figures 5.36 and 5.37. Since cycle times of engine module assemblies are long, it was not possible to collect data more than once during the AIW week. Both assemblies are done by one technician, so one of each AIW forms is prepared for each assembly. HPT Shroud assembly took 6 hours and 27 minutes. AIW target was to reduce it 30 per cent to 4 hours and 31 minutes. LPT Nozzle assembly took 3 hours and 22 minutes. AIW target was to reduce it 30 per cent to 2 hours and 22 minutes.

CHARTER DOCUMENT-0627
DECEMBER 06

DESCRIPTION OF TASK	HPT SHROUD / LPT NOZZLE ASSEMBLY (CFM56-7B)
SCOPE	HPT SHROUD / LPT NOZZLE ASSEMBLY (CFM56-7B)
BOUNDARIES	FROM : INSTALLATION OF HPT SHROUD TO : INSTALLATION OF LPT NOZZLE
DELIVERABLES	• CYCLE TIME REDUCTION • PEOPLE TRAVEL REDUCTION • PRODUCTIVITY INCREASE • POINT OF USE TOOLS (TOOL KIT PREPERATION) • PARTS PRESENTATION (PARTS KIT PREPERATION)
TEAM LEADER	CİHAN AÇIKKOLLU (BUSINESS DEVELOPMENT MANAGEMENT - ENGINEER)
TEAM MEMBERS	• MURAT AYGAN (ENGINE SHOP - ENGINEER) • KASIM AYDEMİR (ENGINE SHOP PPC - TECHNICIAN) • ERCAN BUYUKSAGLAM (ENGINE SHOP - TECHNICIAN)
PREPARATION DATE	13 OCTOBER 2006

LEADERSHIP APPROVAL:

AYHAN GÜCENMEZ ENGINE O/H Shop Chief	17.11.06 MÜJDAT ULUDAĞ ENGINE O/H Shop Mng.	MEHMET TİLLA Bussiness Development Mng.

Figure 5.35. Charter document for HPT shroud & LPT nozzle assembly AIW

Time Observation Sheet

Process Name: HPT SHROUD
Observation Date: 28.11.2006
Observer: Cihan Açıkkollu

Data (top half - stopwatch readings; bottom half - subtraction; right - notes)

	Step No.	Operation Name	1	2	3	4	5	Component Task Time
W	1	Modül arabasının alınması	1'12"					
W	2	Tikaf'ın fotokopisi/ formlarının alınması/hazırlanması IPC - Engine manual	4'35"					
W	3	Takım çantasının alınması	40"					
NEC	4	formun incelenmesi/doldurulması (TIKAF + İş formu)	2'0"					
W	5	Malzemelerin çalışma masasına alınması	20"					
W	6	Case'in standa alınması	10"					
W	7	Malzemelerin arabaya geri konması	10"					
NEC	8	IPC inceleme	2'20"					
W	9	Arabadan malzeme alınması (Shroud)	10"					
NEC	10	IPC inceleme	1'40"					
		Time for 1 cycle						

Figure 5.36. Time observation sheet for HPT shroud assembly (page 1 of 12)

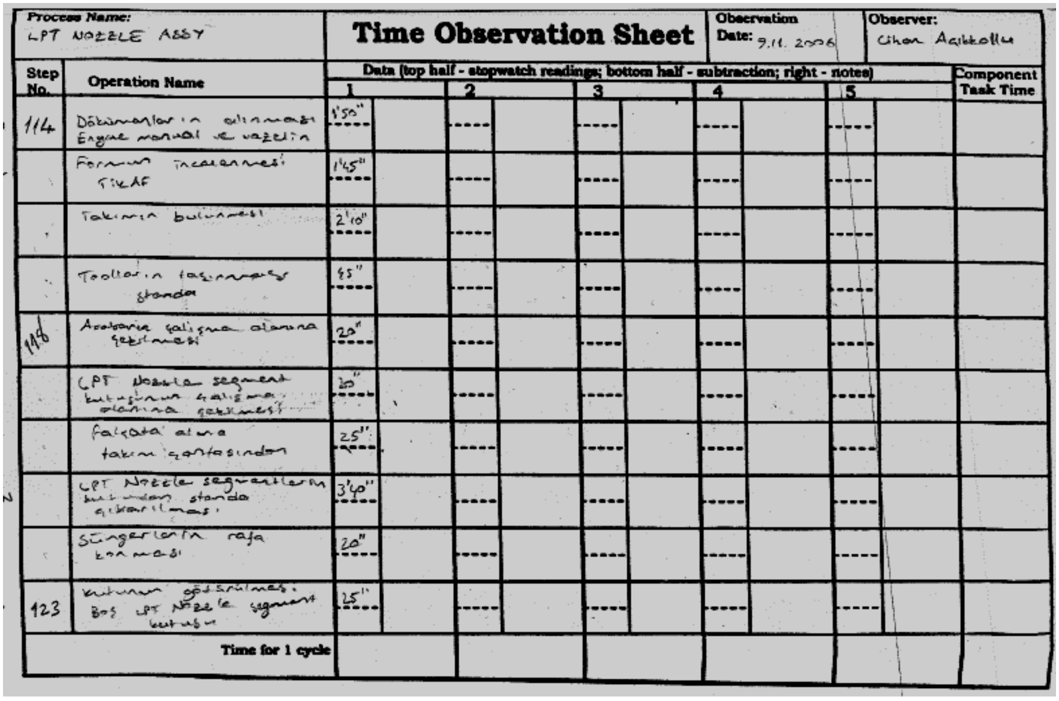


Figure 5.37. Time observation sheet for LPT nozzle assembly (page 1 of 8)

Secondly, time observation sheets were laid on to time axis by using standard work combination sheets (SWCS's) and different kind of process steps, such as manual, automatic, walking and waiting, were color-coded, in order to make the process more visual and find wastes more easily. Figures 5.38 and 5.39 show the first pages of SWCS's of both assemblies:

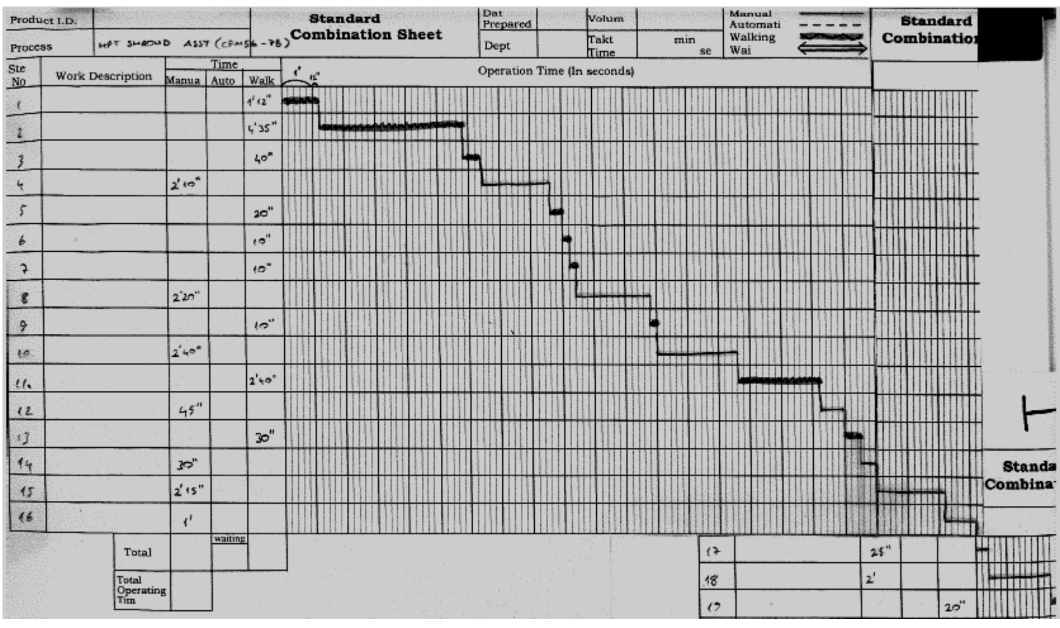


Figure 5.38. First page of standard work combination sheet for HPT shroud assembly

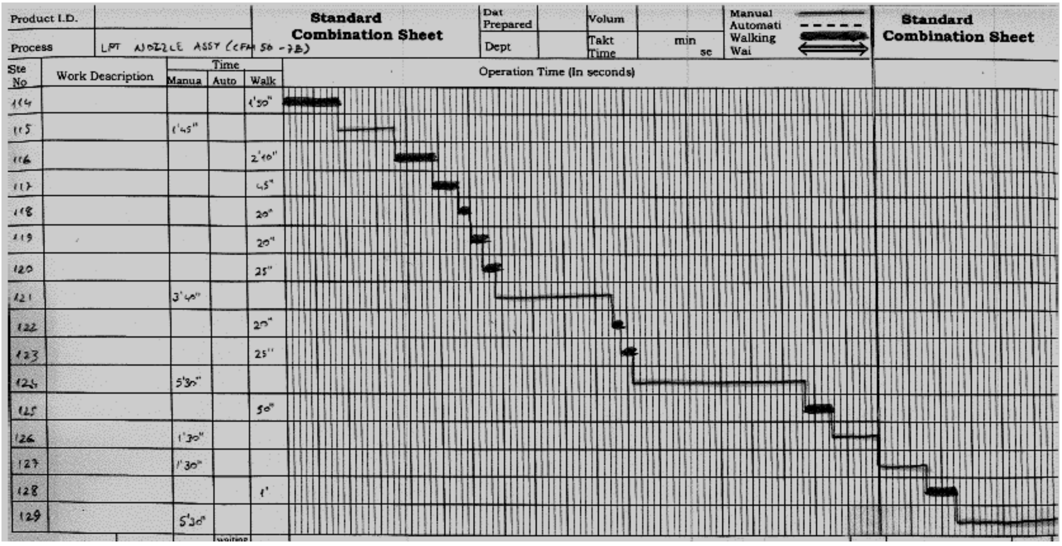


Figure 5.39. First page of standard work combination sheet for LPT nozzle assembly

Next, standard work sheets (spaghetti charts) were prepared for both processes. In Figure 5.40, it can be seen that the technician mostly walked to tool shop, tool shelf, waste bin and shop depot. He traveled 867 meters in total during HPT Shroud assembly. AIW target was to reduce it 30 per cent to 607 meters. For the LPT Nozzle, the technician mostly walked to tool shop and tool shelf (Figure 5.41). He traveled 627 meters in total, during LPT Nozzle assembly. AIW target was to reduce it 30 per cent to 439 meters.

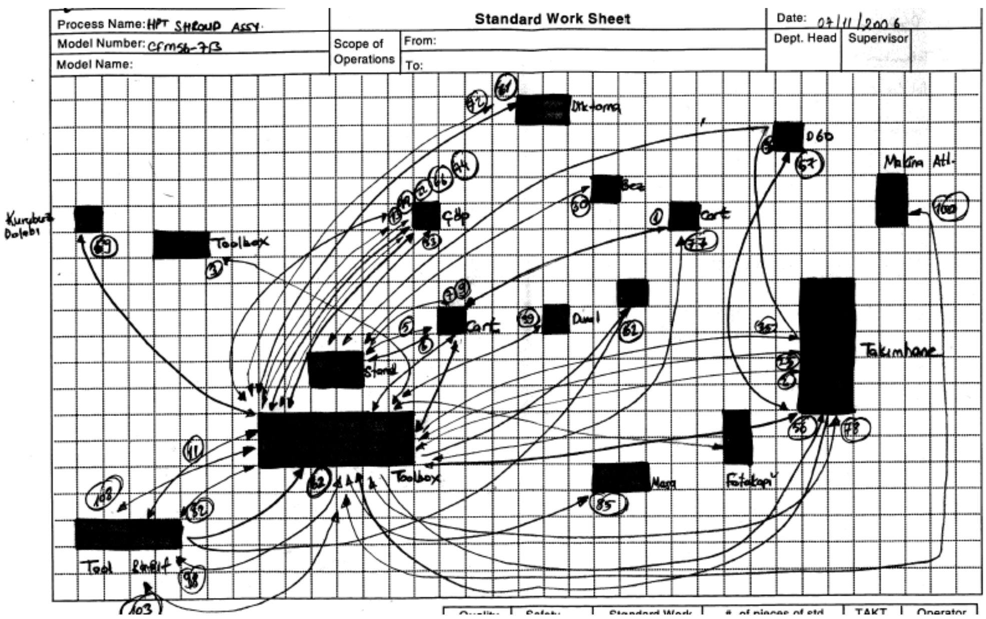


Figure 5.40. Standard work sheet (spaghetti chart) for HPT shroud assembly

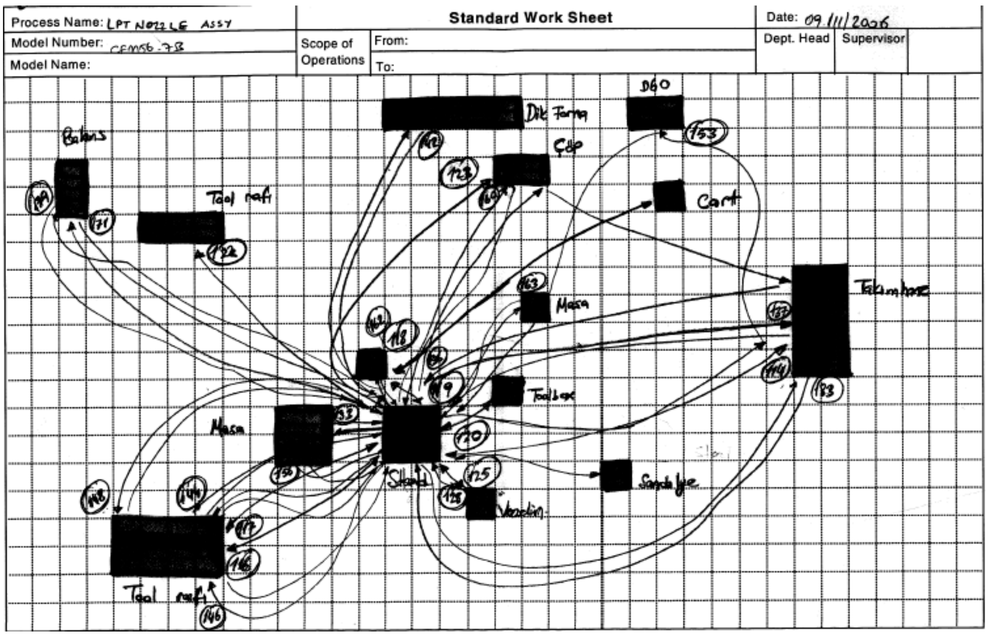


Figure 5.41. Standard work sheet (spaghetti chart) for LPT nozzle assembly

Next, the team analyzed the time observation sheet and identified each step as

- value-added,
- non-value-added but necessary
- or non-value added and unnecessary.

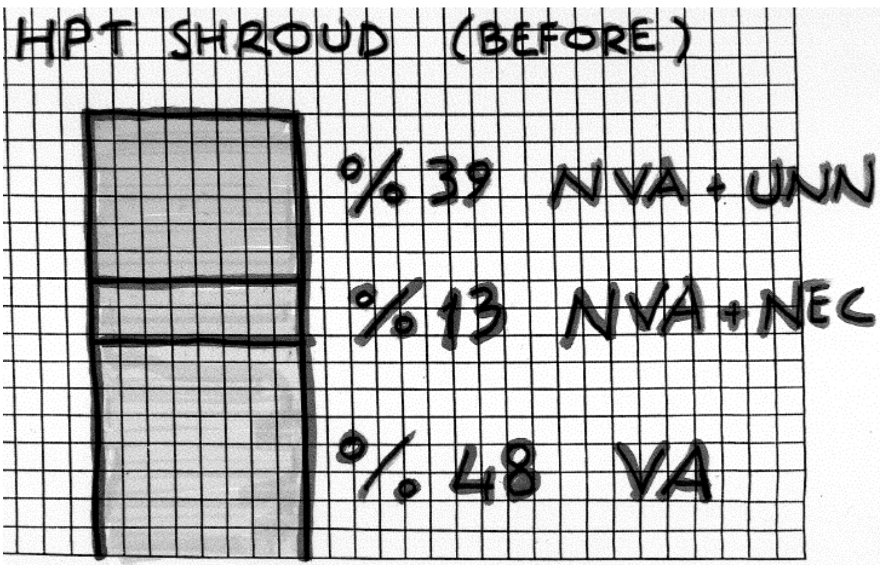


Figure 5.42. Percent load chart for HPT shroud assembly (before AIW)

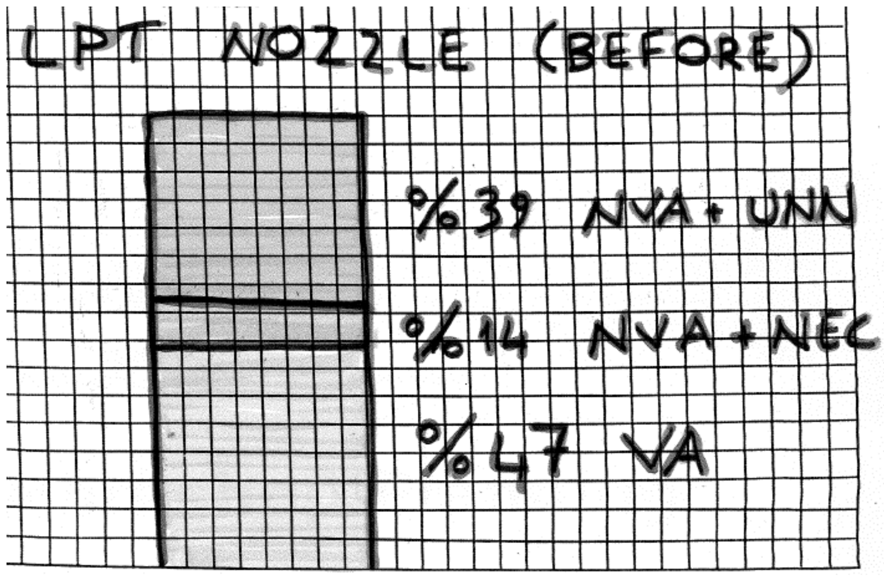


Figure 5.43. Percent load chart for LPT nozzle assembly (before AIW)

The team sorted process steps into three categories and summed up their times. As it can be seen in Figures 5.42 and 5.43, value-added process steps accounted for only 48 per cent and 47 per cent of total cycle times of two assembly processes, which means almost half of each cycle time is waste. Non-value-added but necessary process steps accounted for 13 per cent and 14 per cent of total cycle times and non-value-added and unnecessary process steps 39 per cent for both.

Improvements

Both during data collection and AIW, team produced 15 kaizen items and 14 of them were completed during the AIW week. These kaizen items can be seen in Table 5.6.

Kaizen items #1, #2 and #8 were completed by dedicating an ergonomic workbench for HPT Shroud and LPT Nozzle assembly (Figure 5.44). This workbench has a turntable on it with a brake and its height can be adjusted by a foot pedal.

Kaizen items #3 and #4 were completed by building a tool kit for both assemblies and placing it at this dedicated workbench (Figure 5.45). Since tools used in both processes are similar, one toolkit was found enough.

Table 5.6. Kaizen items for HPT shroud / LPT nozzle assembly

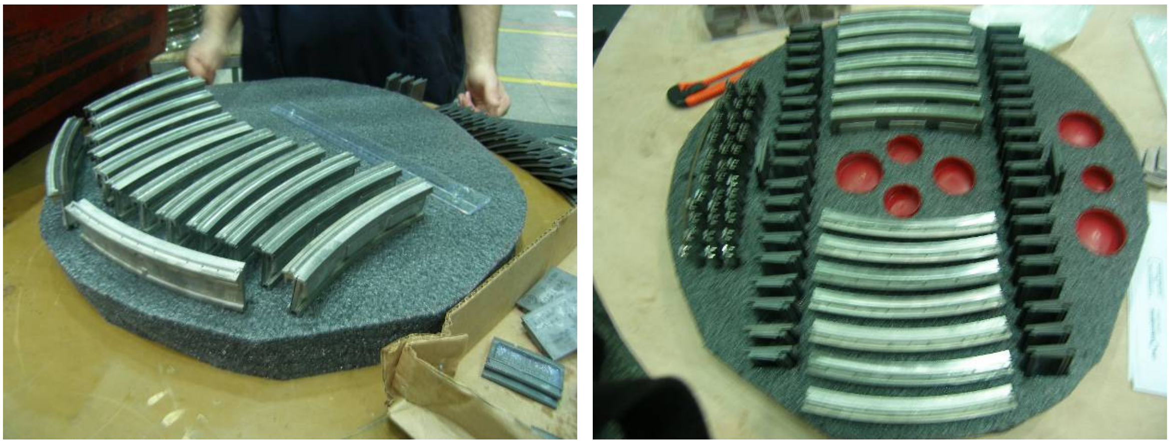
#	Problem Definition	Solution	Resp.	ECD	% Comp.
1	There is not a dedicated workbench for HPT Shroud Assembly. This job is done on any empty workbench in the shop.	Preparing a dedicated workbench for HPT Shroud Assembly (Figure 5.44).	M.A.	**12.12.2006**	**100%**
2	There is not a dedicated workbench for LPT Nozzle Assembly. This job is done on any empty workbench in the shop.	Preparing a dedicated workbench for LPT Nozzle Assembly (Figure 5.44).	M.A.	**12.12.2006**	**100%**
3	Tools used for HPT Shroud assembly are dispersed in the shop. This increases walking and looking for tools.	Preparing a dedicated toolbox for HPT Shroud assembly and placing it at the dedicated work bench (Figure 5.45).	M.A., K.A.	**12.12.2006**	**100%**
4	Tools used for LPT Nozzle assembly are dispersed in the shop. This increases walking and looking for tools.	Preparing a dedicated toolbox for LPT Nozzle assembly and placing it at the dedicated work bench (Figure 5.45).	M.A., K.A.	**12.12.2006**	**100%**
5	HPT Shroud parts come mixed and without any order. It is very time consuming for the technician to find the next part needed. Even though he finds the necessary part, he has to count them in order to check if there is missing.	Improving parts presentation for the assembly. Preparing parts kit for HPT Shroud assembly and making sure that they are designed in the order of technician’s usage (Figure 5.46).	S.S.İ. / K.A.	**12.12.2006**	**100%**
6	LPT Nozzle parts come mixed and without any order. It is very time consuming for the technician to find the next part needed. Even though he finds the necessary part, he has to count them in order to check if there is missing.	Improving parts presentation for the assembly. Preparing parts kit for LPT Nozzle assembly and making sure that they are designed in the order of technician’s usage (Figure 5.46).	S.S.İ. / K.A.	**12.12.2006**	**100%**
7	Seals come in packages of 4 or 5. It is very time consuming for the technician to take more than 100 seals out of packages.	Making sure that seals are taken out of their packages beforehand in the ppc.	S.S.İ. / K.A.	**12.12.2006 EXT 12.08.07**	**75%**
8	Since HPT Shroud and LPT Nozzle cases are big and circular modules, technician has to walk around them very often in order to install hundreds of bushings, bolts and nuts.	Building a turntable for the HPT Shroud and LPT Nozzle workbench (Figure 5.44).	M.A.	**12.12.2006**	**100%**
9	Technician uses manual hand tool for installing almost 100 bolts and nuts. It is very time consuming and ergonomically unfavorable.	Making sure that a battery drill is present on the workbench.	M.A.	**12.12.2006**	**100%**

10	Documents needed for assembly stay in the tool shop and each time technician has to take a photocopy of them (Illustrated Parts Catalog, Engine Manual, etc.).	After dedicating a workbench for HPT Shroud and LPT Nozzle assembly, placing necessary documents on this workbench and making sure that revisions are followed as necessary.	M.U.	**12.12.2006**	**100%**
11	Omega rings come in very tight square packages. Technician spends too much time to take them out.	Making sure that two sides of the square packages are opened beforehand in the ppc (Figure 5.47).	S.S.İ. / K.A.	**13.12.2006**	**100%**
12	Part numbers and necessary amount of each part are not written on the part kits.	Labeling part kits as necessary.	S.S.İ. / K.A.	**13.12.2006**	**100%**
13	Most of the big tools stay on the tool shelves.	Building a small dedicated cart for big tools and placing it right next to the dedicated workbench for HPT Shroud and LPT Nozzle assembly (Figure 5.48).	M.A.	**14.12.2006**	**100%**
14	C-Clips pump stays in a case on tool shelf.	Placing C-Clips pump ready for using at the dedicated workbench.	M.A.	**14.12.2006**	**100%**
15	It is very hard to control gap between clips and shrouds while installing clips on shrouds with pump. Too much rework needed.	Building an L-shaped special tool with 0.017 inch thickness (Figure 5.49).	M.A.	**14.12.2006**	**100%**

Items #5 and #6 were completed by preparing part kits and making sure that those parts come in these kits. Kits were designed by the technician and the PPC technician together according to technician's ease and order of use. Without kitting, parts used to come mixed on the cart and it was very time consuming for the technician to find the necessary part among all. Even though he finds, he could not be sure without counting whether any part is missing.

Figure 5.44. Dedicated workbench for HPT shroud and LPT nozzle assembly

Figure 5.45. HPT shroud and LPT nozzle assembly tool kit



(a) (b)

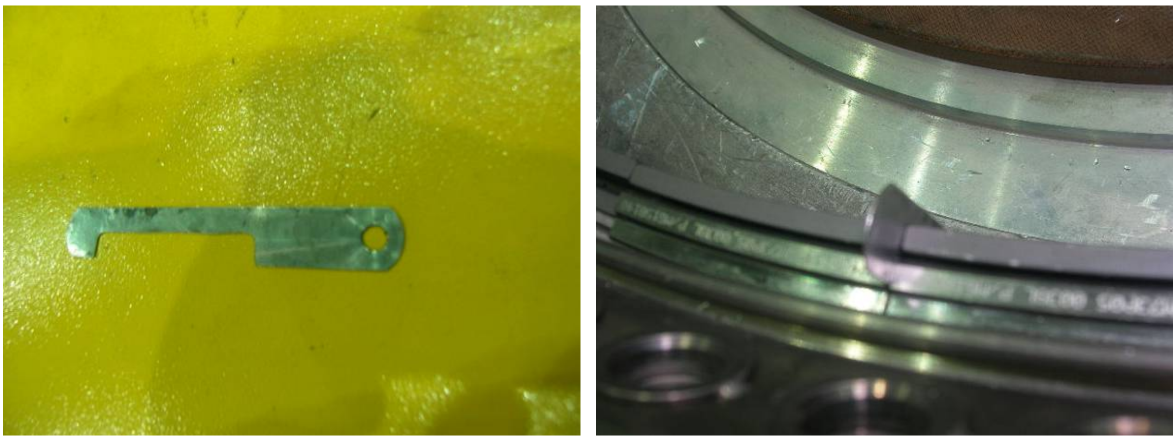
Figure 5.46. Technician designing the part kit for his ease of use (a) and final part kit (b)

Kaizen item #9 was closed by placing a battery drill on the dedicated workbench. Item #10 was completed by putting the necessary documents on the workbench and tracking their revisions from there. Kaizen item #11 was about omega rings, which used to come in tight square packages (Figure 5.47). Technician had to take the package from the cart, put it on the workbench, take his knife, cut two sides of the package, take the omega rings out and put the empty package back on to the module cart. Kaizen item suggests that two sides of the square package should be cut beforehand in the PPC. Now, the technician only opens one corner of the package and takes the rings out.

Figure 5.47. Omega rings used to come in tight square packages.

Figure 5.48. Special tool cart for HPT shroud and LPT nozzle assembly

Item #12 was closed by improving part kits by shadowing parts and adding their part numbers on the kit, so that the technician does not have to look at the manuals and make sure that it is the correct part. Item #13 was about big tools staying on the tool shelves. Now that there is a dedicated workbench for both assemblies, team suggested building a special tool cart for this tools and placing it right next to this dedicated workbench. This tool cart can be seen in Figure 5.48.



(a) (b)

Figure 5.49. 0.017 inch thick special tool (a) for controlling the gap (b) between shrouds and clipses during clips installation

Item #14 was completed by placing C-Clips pump at the dedicated workbench. Finally, item #15 was completed by building a special tool for controlling the gap between shrouds and clipses during clips installation using the pump (Figure 5.49).

Results

Team completed all of the kaizen items except #7 before Wednesday evening and started to measure the improved process on Thursday morning as planned. All forms were prepared for the improved process and presented with the before-AIW forms in the final report-out on Friday evening. In Figures 5.50 and 5.51, it can easily be seen that technician movements during both assemblies are much simpler and lean when compared to before-AIW forms in Figures 5.40 and 5.41.

Figure 5.52.a shows the percent load chart for HPT Shroud assembly after the improvements. If we compare it with Figure 5.42, it can be seen that the percentage of value-added process steps decreased from 48 per cent to 37 per cent for HPT Shroud assembly, whereas non-value-added but necessary steps increased from 13 per cent to 22,7 per cent and non-value-added and unnecessary steps increased from 39 per cent to 40,3 per cent. This is mostly because improvements on this process decreased times of value-added steps more than non-value-added steps. For example, using turntable and battery drill instead of manual hand tool decreased the time for bolt and nut installation significantly and using new L-shaped tool decreased the time and rework needed for clips installation.

On the other hand, for LPT Nozzle assembly, when we compare Figure 5.52.b with Figure 5.43, it can be seen that the percentage of value-added steps increased significantly from 47 per cent to 66½ per cent, whereas non-value-added but necessary steps increased from 14 per cent to 25,6 per cent and non-value-added but necessary steps decreased from 39 per cent to 7,9 per cent.

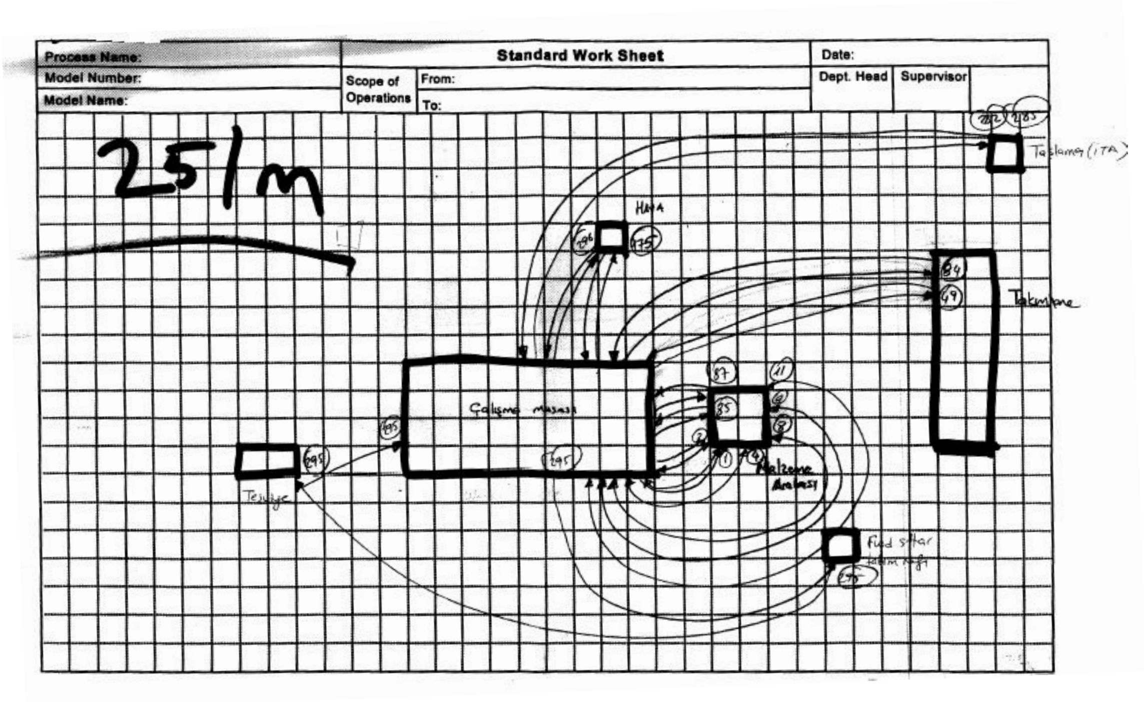


Figure 5.50. Standard work sheet (spaghetti chart) for HPT Shroud assembly after improvements

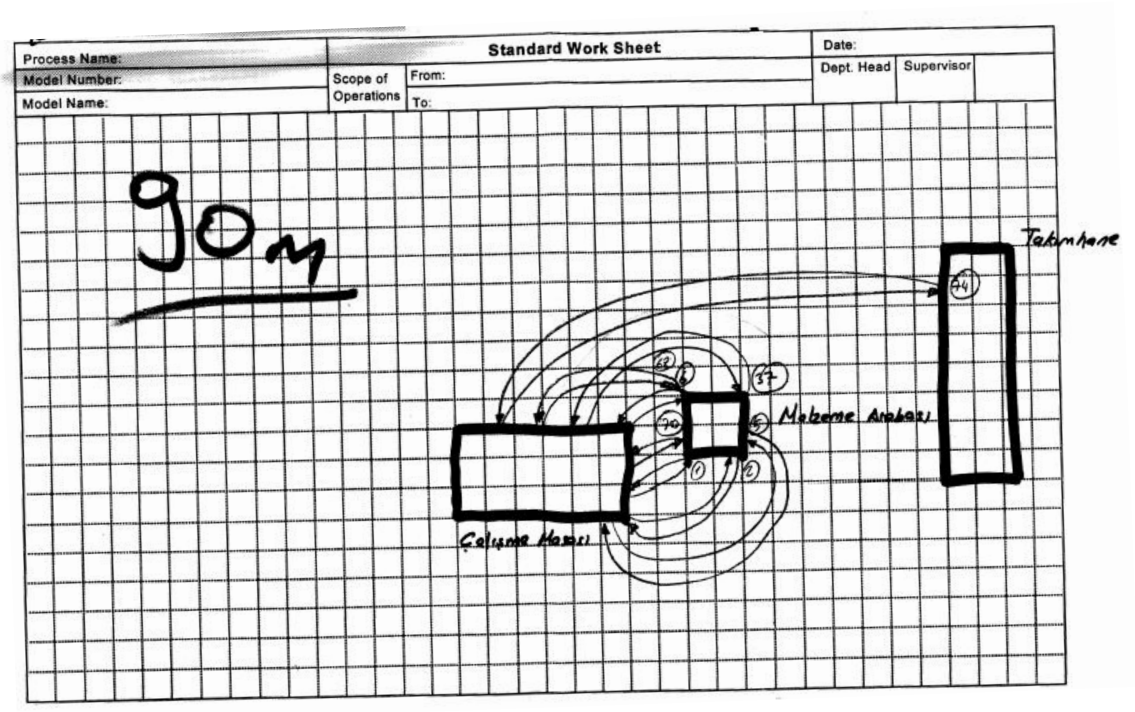
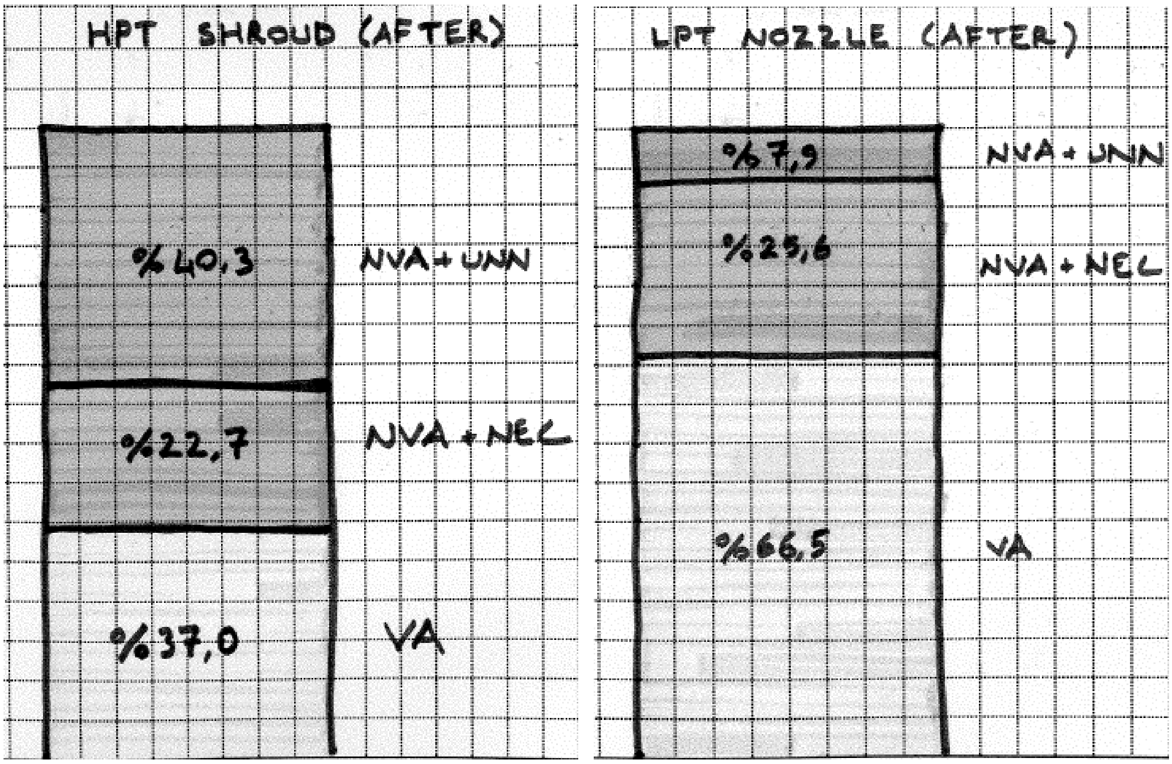


Figure 5.51. Standard work sheet (spaghetti chart) for LPT Nozzle assembly after improvements

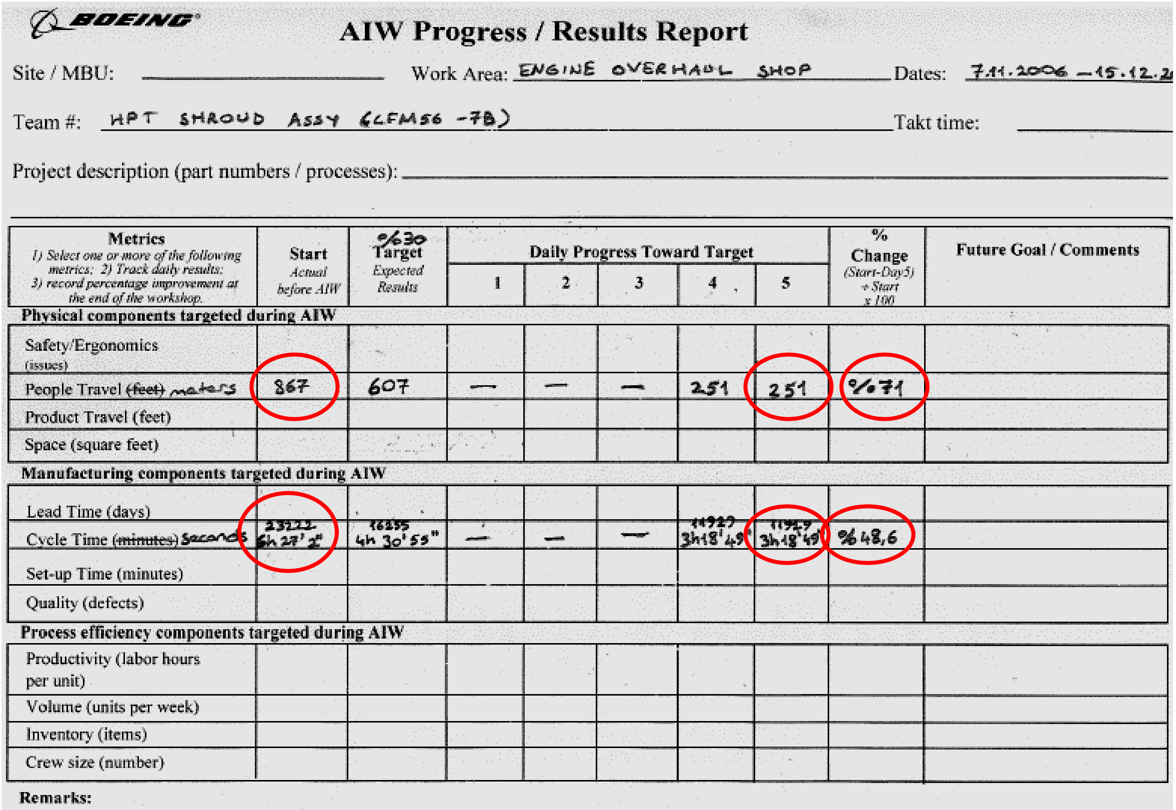


(a) (b)

Figure 5.52. Percent load charts after improvements for HPT shroud assembly (a) and LPT nozzle assembly (b)

Finally, the results of the AIW are shown in AIW Progress Results Reports (Figures 5.53 and 5.54). It can be seen that, technician used to walk 867 meters for HPT Shroud assembly before improvements. AIW target was to decrease it 30 per cent to 607 meters and the result is a 71 per cent decrease to 251 meters. Moreover, HPT Shroud assembly used to take 6 hours and 27 minutes. AIW target was to decrease it 30 per cent to 4 hours and 31 minutes and the result is a 48.6 per cent decrease to 3 hours and 18 minutes.

For the LPT Nozzle assembly, technician used to walk 627 meters as it is shown in Figure 5.54. The target was to decrease it 30 per cent to 439 meters and the result is a striking 86 per cent decrease to only 90 meters. Furthermore, cycle time for LPT Nozzle assembly used to be 3 hours and 22 minutes, whereas the target was to decrease it 30 per cent to 2 hours and 21 minutes. The result of the AIW is a 54.7 per cent decrease to 1 hour and 31 minutes.



BOEING

AIW Progress / Results Report

Site / MBU: ______ Work Area: ENGINE OVERHAUL SHOP Dates: 7.11.2006 – 15.12.2[illegible]

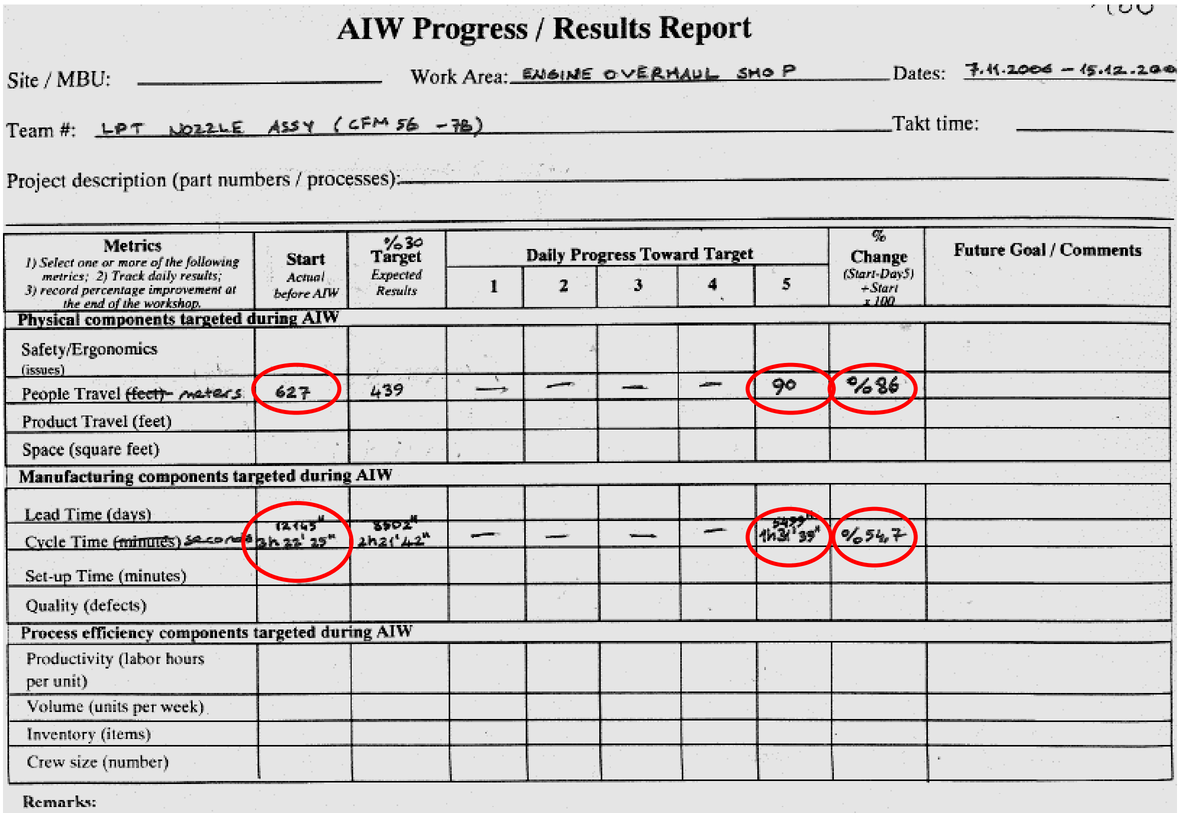
Team #: HPT SHROUD ASSY (CFM56 -7B) Takt time: ______

Project description (part numbers / processes): ______

Metrics *1) Select one or more of the following metrics; 2) Track daily results; 3) record percentage improvement at the end of the workshop.*	Start *Actual before AIW*	%30 Target *Expected Results*	Daily Progress Toward Target 1	2	3	4	5	% Change *(Start-Day5) ÷ Start x 100*	Future Goal / Comments
Physical components targeted during AIW									
Safety/Ergonomics (issues)									
People Travel ~~(feet)~~ meters	867	607	—	—	—	251	251	%71	
Product Travel (feet)									
Space (square feet)									
Manufacturing components targeted during AIW									
Lead Time (days)									
Cycle Time ~~(minutes)~~ seconds	23222 6h 27' 2"	16255 4h 30' 55"	—	—	—	11929 3h18'49"	11929 3h18'49"	%48,6	
Set-up Time (minutes)									
Quality (defects)									
Process efficiency components targeted during AIW									
Productivity (labor hours per unit)									
Volume (units per week)									
Inventory (items)									
Crew size (number)									

Remarks:

Figure 5.53. AIW progress/results report for HPT shroud assembly



AIW Progress / Results Report

Site / MBU: ______ Work Area: ENGINE OVERHAUL SHOP Dates: 7.11.2006 – 15.12.200[illegible]

Team #: LPT NOZZLE ASSY (CFM 56 -7B) Takt time: ______

Project description (part numbers / processes): ______

Metrics *1) Select one or more of the following metrics; 2) Track daily results; 3) record percentage improvement at the end of the workshop.*	Start *Actual before AIW*	%30 Target *Expected Results*	Daily Progress Toward Target 1	2	3	4	5	% Change *(Start-Day5) ÷ Start x 100*	Future Goal / Comments
Physical components targeted during AIW									
Safety/Ergonomics (issues)									
People Travel ~~(feet)~~ meters	627	439	→	—	—	—	90	%86	
Product Travel (feet)									
Space (square feet)									
Manufacturing components targeted during AIW									
Lead Time (days)									
Cycle Time ~~(minutes)~~ seconds	12145" 3h 22' 25"	8502" 2h21'42"	—	—	—	—	5499" 1h31'39"	%54,7	
Set-up Time (minutes)									
Quality (defects)									
Process efficiency components targeted during AIW									
Productivity (labor hours per unit)									
Volume (units per week)									
Inventory (items)									
Crew size (number)									

Remarks:

Figure 5.54. AIW progress/results report for LPT nozzle assembly

Table 5.7. Results of the AIW for HPT shroud sssembly

	Before AIW	**Target**	**After AIW**	**Improvement**
Cycle time	6 hours 27 mins	4 hours 31 mins	3 hours 19 mins	49%
Technician travel	867 meters	607 meters	251 meters	71%
Value-added / total cycle time	48%	62%	37%	- 23%
Non-value-added / total cycle time	52%	36%	63%	- 21%

Table 5.8. Results of the AIW for LPT nozzle assembly

	Before AIW	**Target**	**After AIW**	**Improvement**
Cycle time	3 hours 22 mins	2 hours 22 mins	1 hours 32 mins	55%
Technician travel	627 meters	439 meters	90 meters	86%
Value-added / total cycle time	47%	61%	67%	43%
Non-value-added / total cycle time	53%	37%	33%	38%

6. DISCUSSION

This section provides an in-depth discussion about the results of the study as related to the objectives of the study. First of all, in the C-Check Package VSM, results showed that bringing different functions in one place by creating a cell eliminates much of the waste inside the process and enables continuous flow of value. Future studies should be conducted in order to find and balance the work loads of each work station in order to prevent a possible bottleneck. Also, parallel cells can be considered for different types of aircraft models or maintenance types. Moreover, internal processes of customer airlines and subcontractor firms most probably contain too much waste. Thus, lean workshops should be extended to include customers, suppliers and subcontractors. This will enable to make the whole MRO industry lean. Otherwise, improvements will be limited to some extent.

In the C-Check Package VSM, wait times between departments were taken as the expected values. For example, if packages are transferred from one office to the next once a day, then the expected wait time of a package was taken half a day. This means that, there is a variance in the lead time and it creates some problems such as in a random moment, we can not be sure where the package is and what percent of the package is complete. By changing to a cell structure, we will make sure that the package is at its dedicated place and it is processed real time with the maintenance as one piece flow.

One difference of MRO from serial production is that processes are longer. For example, an assembly of an engine module takes ten hours and some tasks take days. This creates some problems in terms of data collection, since in most cases there is not an opportunity to collect data more than once during a workshop, which in turn increases the variance of data. Thus, a possible way to tackle this problem is to divide big processes into manageable and meaningful sub-processes and conduct two or three successive workshops to cover the whole process. Or, alternatively conduct one workshop for the whole process and accept the variance in data.

MRO sector differs from serial production also in terms of inventory levels between processes. For example, maintenance packages are prepared according to a maintenance plan and each package is different from others depending on the aircraft and the type of maintenance. Also, it should be prepared as late as possible before maintenance, in order to be accurate and include latest changes in maintenance documents. This prevents building a supermarket and let the downstream process pull from here and control the system with kanbans. So, building a cell and making the package flow continuously seems a good improvement for the first step, but in order to maintain the sustainability of the new system and improve it further, VSM workshops should be conducted periodically for the same process.

Aircraft engines are tracked by their serial numbers. When a customer sends an engine for overhaul, they want the same exact engine back, not a different one. Since it is not logical to let an aircraft wait on ground for engines, airlines either have spare engines in-house or they rent them in order to continue operations. But, they do not have to rent from the MRO they give their engines for overhaul. This makes it difficult for an MRO to build a pull system. However, for Turkish Airlines' engines, Turkish Technic can give another engine of the same type. Thus, a pull system can be possible for Turkish Airlines' engines. But, there is a strategic decision here, since they are separate companies now, Turkish Airlines might go to another MRO who provides higher quality service with lower cost and in shorter time. Another possible option for the engine overhaul might be building a continuous FIFO (First In First Out) line fed with cells, at least for the final assembly. This will surely eliminate most of the waste in the process. However, engine overhaul shop operates in a very old building and facility might restrict this change. But, there is a plan to move the engine shop to a new building and this building might be designed for doing the engine overhaul in a continuous FIFO line.

The same is true for all high volume components like engine. Building a continuous FIFO line fed with cells will eliminate most of the waste in processes and reduce lead time significantly. For the aircraft, a similar approach might be followed. In the current situation, aircrafts are taken into the hangar in a very crowded way. So, for example, in order to remove an aircraft out of the hangar, at least one or two aircrafts must be removed first from their positions. Also, there is a central toolshop for special tools and platforms are stored between two hangars. This creates a lot of Non-Value-Added tasks for technicians such as bringing necessary platforms, waiting in toolshop for taking the necessary tools, going back to aircraft or removing aircrafts from their positions, etc. A possible vision for the aircraft maintenance might be building a continuous pulse line consisted of five or six stations, such as:

- 1st station: Cleaning, incoming tests, removing cabin interior components such as seats, galleys, lavatories, panels, stowage bins, carpets, etc.
- 2nd station: Structural maintenance
- 3rd station: Avionics maintenance
- 4th station: Reinstalling cabin interior components
- 5th station: Painting
- 6th station: Finishing

In each station there should be fixed platforms for the necessary areas of the aircraft. So that technicians will not have to prepare these for each maintenance. Also, tools necessary for each station should be placed on these fixed docks ready for use. This will further eliminate going to toolshop, waiting in queue, waiting for the necessary tools for the task and going back to the aircraft. Such a system will eliminate a big portion of the Non-Value-Added tasks conducted in the current situation. Also, since days spent in each station is fixed and known, planned and actual maintenance durations will be more accurate and customer satisfaction will improve.

Another difference of MRO sector from serial production is that some portion of the tasks conducted are non-routine tasks, such as defects, damage, modifications, etc. This makes standard work, the foundation stone of lean, very difficult. However, there are still a lot of routine tasks which are the low hanging fruits for a lean transformation.

A good start might be a very problematic, maybe a bottleneck process, where improvements will be felt by everyone in the company. This will facilitate the buy-in of all employees. Soft skills like leadership, communication and team work are as important as hard skills like using lean tools effectively. Commitment, dedication and support of top management are must for a lean transformation. Also, a powerful leader as a change agent supported by lean practitioners is very important for the success of a lean initiative.

Organization of the company should be changed from functional silos to value streams representing product (or service) families. Levels of the organization should be reduced in order to provide better communication throughout the company. Legacy accounting metrics should be changed with lean accounting metrics in order to prevent creating waste in the system, such as excess WIP or finished goods inventory. Opponents of change should be tried to persuade by explaining the need for change and showing the benefits. Then, those who do not change their manner should be eliminated from the system.

For the first years of lean transformation, support from a consultant company is necessary. During this period, lean leaders should be trained in each department in order to facilitate the change. Then, consultant support should be decreased step by step and the company should be able to continue itself. Moreover, targets should be aggressive, since there are a lot of opportunities in a company starting a lean transformation as can be seen in the results of this thesis. In order to achieve sustainability and continuity, yearly workshop plans should be prepared. Workshops for the same process should be conducted periodically in order to maintain continuous improvement. Also, follow-up kaizen walks should be done periodically for the kaizen items that could not be completed during the workshops. A kaizen office should be founded in order to coordinate all these efforts and work as in-house consultants. But, giving all responsibility to this office for lean transformation will most probably turn into a failure, since departments and middle management should be responsible for improving their own processes.

During two years, more than 40 workshops were conducted in Turkish Technic and data showed that VA (Value-Added) tasks are about 30-40 per cent of the whole process. This situation is most probably the same in other companies that newly started a lean journey. A common mistake done by companies is to suppose that the process is only composed of VA tasks and focus on this portion of the process in order to improve the performance. Thus, companies spend millions of dollars to buy faster machines, more expensive tools, equipment, etc. However, most of them overlook non-value-added activities inside their processes and return of their investments is limited with the VA part of the process, which is generally 30-40 per cent of the whole. This is mostly because they do not define value from the customers' point of view. The thing that must be done is to focus on the whole value stream and find wastes inside it. Then, focus on these non-value-added activities first and try to eliminate them by achieving a continuous flow of value. This can be accomplished by spending almost no money and it will improve the performance of the process 60-70 per cent.

Lean is not a project with a deadline. It is a radical change of a company's management system. It affects not only all employees of a company, but also its suppliers, partners and customers. So, lean needs a long term commitment and support from top management. As stated in 2.5.1, business decisions should be based on a long term philosophy, even though sacrificing short term financial targets.

During the workshops in Turkish Technic, people had a natural resistance to change, although it was beneficial for them. This was partly because of fearing from new unknown situation and having to leave old habits and practices. At this point, leadership played an important role. Fear of the unknown could be defeated partly by communicating the need for lean and making sure that everybody understood and believed in the benefits of it. Also, the leader should make sure that everybody understands that the aim of lean is to eliminate waste, not people. Thus, management should guarantee that nobody will be laid off because of improvements and value-added tasks will be created for excess employees.

The fear of leaving old habits and practices can be defeated by aligning the personal benefits of people with the company's. This can be achieved by a performance measurement system and sharing the benefits of improvements with employees. At this point, strong team players should be encouraged and rewarded, rather than those trying to achieve alone. Also, lean champions should be recognized and rewarded. It can be a small reward in terms of money, for example a dinner in a good restaurant, but its affect will be huge when compared to its cost. Leaders should also act as teachers who have theoretical and hands-on experience in the workshops and, by asking the right questions, empowers people to make the change happen.

Lean is much more than just a set of tools. It is not a project that has a certain date of completion either. Lean is an endless journey towards perfection. Actually, Lean starts with the customer. It puts the customer into the center and forms the business model around it, according to what really is a value for the customer. It is a common mind set of all employees of a company, which focuses on the fact that “every process can be improved”.

Lean aims to eliminate all waste inside any process and its principles could be applied for any process containing waste. From this point of view, it is a superior way of production and service that must be applied in every industry. It will help improve the effective use of a country’s resources and increase its competitive power in the global competition.

7. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1. Summary of the Study

The aim of this study was to show that lean principles can be used for increasing productivity in an MRO company. VSM, 5S and AIW methods of lean were applied on different processes and workplaces of Turkish Technic MRO Company.

C-Check Package VSM enabled us to look at the process from a broader view and see the wastes, which prevented continuous flow of value. In the future state, for the processes before maintenance, package travel will be reduced from 299 meters to 200 meters, cycle time from 1½ days to ½ days and lead time from 2½ days to 1 day. Improving the process before maintenance will enable planners to prepare the package later, which makes it more accurate since it will include last minute changes about maintenance documents.

A maintenance package should be processed immediately during or after maintenance in order to prepare and send the invoice as soon as possible. This is very important in financial terms for any company. In the current state, Turkish Technic can prepare the invoice 9½ days after the maintenance, on average. Package is processed in a batch manner and visits many departments for different tasks. This creates a lot of non-value-added time for the package such as wait and transfer. By bringing these different functions in one place as a cell structure and by building a rack system in order to control and manage maintenance documents, package can be processed concurrently with the maintenance as one-piece-flow. This new state will bring down the time spent after maintenance from 9½ days to just 1½ days, which means collecting revenues eight days earlier for each maintenance. Also, package travel will be reduced from 512 meters to 60 meters and cycle time from 3½ days to 1 day, in the future state.

This thesis also showed that 5S, which is the foundation for a lean culture, provided an organized and efficient work place. It eliminated safety and ergonomics problems related with the area. Also, it provided more efficient use of work area by removing unnecessary items and placing the necessary ones closest to the places they are needed, according to their frequency of usage. Determining a specific place for everything and making it more visual by labeling and shadowing made problems more visible and reduced the time necessary for searching and set-up.

Furthermore, Accelerated Improvement Workshops helped us focus on and improve more specific processes. Three of the module assembly processes, which directly affect turn around time of the engine, were analyzed in detail and improved significantly. Cycle time for HPC Forward Case assembly was reduced 67 per cent, whereas technician travel for the same process was reduced 89 per cent and value-added portion of total cycle time was increased 93 per cent. Also, for HPT Shroud Assembly, cycle time was reduced 49 per cent and technician travel was reduced 71 per cent. However, value-added portion of total cycle time decreased 23 per cent. This was due to decreasing total time of value-added processes more than non-value-added processes. Moreover, cycle time of LPT Nozzle Assembly was reduced 55 per cent, technician travel was reduced 86 per cent and value-added portion of total cycle time was increased 43 per cent.

Another result of the thesis is that 5S and AIW methods improved safety and ergonomics conditions of the work places.

- In the stands and ladders 5S workshop:
    - unsafe stands and ladders were repaired, and
    - new ones were built for the necessary areas of the aircrafts.

- In the tool shop 5S workshop:
    - proper carts for tools were prepared in order to make sure that each tool is stored safely and in good condition,.
    - wheels were mounted under tool carts in order to make transportation easier, and
    - light tools were removed from crates and hanged on the wall for providing an easier reach.

- In the seat shop 5S workshop:
    - a more ergonomic reach for tools were achieved, and

  - low stools with wheels were provided for a more ergonomic work posture.

- In the HPC Forward Case AIW:
  - a battery drill was provided for the technician, instead of manual tool,
  - preparation of a proper ergonomic tool for applying RTV chemical was added as an action item,
  - a turntable with adjustable height was prepared for a more ergonomic work,
  - a hook was built for the air hose, so that it is always ready to use, and
  - kits were prepared for an easier reach for the parts.

- Finally, in the HPT Shroud / LPT Nozzle AIW,:
  - a turntable with adjustable height was prepared for a more ergonomic work,
  - kits were prepared for an easier reach for the parts, and
  - a battery drill was provided for the technician, instead of manual tool.

One more result of this thesis was that when trying to establish a lean culture in a company, soft skills like leadership, team work and communication played an important role as much as hard skills like using the lean tools correctly. Since this is not a quantitative hypothesis, it is very hard to measure and prove it.

7.2. Conclusions

In this study, three lean manufacturing methods, 5S, VSM and AIW, were tested in a non-manufacturing environment, Turkish Technic MRO Company. Even though lean has many more methods to improve a company's processes, the other methods were out of the scope of this study and they are subject to future research. Results of the study showed that there are a lot of improvement opportunities in MRO companies if lean methods are applied properly.

The problem with the current state of C-Check Package process is that, after the maintenance, package travels many departments for different tasks and it is processed in a batch manner. This means frequent and long interruptions for the value stream, such as wait and travel. The proposed future state of the process will synchronize the tasks with the maintenance as one-piece-flow. This will provide three major benefits for Turkish Technic. First of all, invoices will be prepared, sent and revenues will be collected earlier and this will increase the competitive advantage of the company in financial terms. Secondly, technicians, who are the surgeons of the aircrafts, will not have to wait in queue and enter man-hours into the system for each task they complete, since this will be done by Maintenance Support and Follow-Up (MSFU) office. Thirdly, MSFU office will also take some of the routine and low-quality tasks of technical controllers, who are the most experienced head technicians of the company. These technicians will have more time for high-quality tasks such as engine run-up, pressurization, fuel tank tasks, etc.

A 15 month implementation plan was proposed for the transformation process. First of all, a room will be arranged for conducting pilot studies. Necessary hardware and software will be provided for this room and employees will be selected from functional departments for pilot study. Their accounts and authorizations will be prepared and pilot study will be announced to everyone after selecting the package for simulation. Then, a pilot study will be conducted for one aircraft package and problems will be determined and solved. Then, second and third pilot studies will be conducted for one package, if necessary. When the process is smooth enough, two and three checks at the same time will be tried. Then, new process will be used for the C or equivalent checks of all types of aircrafts. Finally, new process will be applied for all types of checks and aircrafts.

Performed 5S workshops aimed to provide an organized and efficient workplace, where there is no unnecessary item; everything has a dedicated and labeled place at the closest possible place they are needed. Also, technician travel and search for needed tools or materials are aimed to be minimized.

Stands and ladders 5S workshop decreased search and carry time of technicians for necessary platforms by removing unnecessary ones, determining a dedicated place for necessary ones, color-coding them and providing a transport way for easy access and removal. Also, platforms are placed closer to the areas they are needed, and safety and ergonomics conditions of the area were improved.

Tool shop 5S increased the area efficiency by removing unnecessary tools and removing light tools from crates and hanging them on the wall. A dedicated place for each tool was determined, labeled and color-coded, in order to minimize search time. Moreover, safety and ergonomics conditions of the area were improved by building proper boxes for each tool, putting wheels under heavy crates and hanging light tools on the wall.

Moreover, seat shop 5S provided extra space by removing unnecessary items from the area. Shop layout was changed in order to improve the flow of seats, a dedicated place was determined for each item and visual controls were created. Documents in the shop were organized and ergonomics condition of the area was improved by providing low stools for technicians.

Furthermore, Accelerated Improvement Workshop (AIW) methodology of Boeing was applied on the assembly processes of HPC Forward and HPT Shroud / LPT Nozzle modules of aircraft engines. Aims of the AIWs were decreasing cycle times, technician travels, quality and ergonomics problems related with the processes and workplaces. Results of the AIWs were impressive. Cycle times of these three processes decreased between 49 and 67 per cent; technician travels decreased between 71 and 89 per cent. These significant improvements are mostly due to part and tool presentations, which are the two low hanging fruits for companies newly started a lean initiative.

Although MRO companies are new to lean principles, this thesis showed that when applied properly, at least VSM, 5S and AIW methods of lean production can be very beneficial for MRO companies. Other tools of lean production such as pull, kanban, jidoka, JIT (Just in Time), TPM (Total Productive Maintenance), heijunka, setup reduction, takt time, theory of constraints, etc. should be tested in the future studies.

7.3. Study Contribution and Future Directions

MRO business has uncertainties in its nature. These might be non-routine work items of an aircraft or different failures of the same component, etc. Thus, establishing standard work is very hard for some processes when compared to a serial production company. However, there are also a lot of routine tasks performed in a standard way, especially in the back shops. This means a lot of opportunity for improvement. The main contribution of this study is providing a case study showing that lean techniques can be useful for increasing productivity, improving safety and ergonomics conditions and financial performance of an MRO company, which operates in different conditions than serial production companies. This thesis is one of rare studies conducted in MRO sector and C-Check Package VSM includes tasks conducted both in office and hangar environments.

A future direction for Turkish Technic or any other company might be applying VSM tool for all main processes. Then, applying 5S and AIW methods to those processes detected as problematic or bottleneck in the value stream. For the C-Check Package VSM, work loads of each work station in the cell should be measured and balanced in order to achieve a smooth flow of value. Depending on the work loads, number of workers should be determined and parallel cells might be built for different types of maintenances or aircrafts, if necessary. Also, internal processes of customers and subcontractors should be measured and improved in order to improve the whole value stream. In the future, VSM workshops might be conducted periodically for this process in order to sustain and standardize the gains and improve the process further.

Another future direction for Turkish Technic might be providing dedicated workplaces for tasks and place each tool, material, document, etc. needed to perform the task, at the point of use. This is relatively simple in the back shops, which do not have too many different components and have enough area. However, it can also be achieved in the hangar by using fixed docks for aircrafts during maintenance. So that, technicians will not have to carry stands, ladders, tools or materials to their workplace on the aircraft. Everything will be ready for them at the point of use. This will eliminate an enormous amount of non-value-added tasks such as transportation and set-up. In order to achieve this, first of all the company must solve the capacity problem. At the moment, sometimes there might be nine or ten aircrafts inside the hangar at the same time, whereas there will be only four or five, if fixed docks are used.

Still another future direction for companies might be applying ergonomics principles in order to support lean efforts. Although we improved the ergonomics of the work areas to some extent, second level might be conducting a through workshop for ergonomics improvements. In this workshop, operator and task parameters can be measured and improvements can be done by using ergonomics principles.

In this study, three lean tools, 5S, VSM and AIW, were applied and provided significant improvements in an MRO company. A future direction for researchers might be applying other tools of lean manufacturing such as pull, kanban, jidoka, JIT (Just in Time), TPM (Total Productive Maintenance), heijunka, setup reduction, takt time, TOC (Theory of Constraints), etc. to an MRO company in order to see the results or applying lean methods in companies from other industries than automotive.

Successful implementations of lean principles in all sectors will definitely result in more effective and efficient use of a country’s resources. This will in turn increase the competitive power of that country in the global competition. Thus, lean principles should be applied wherever possible.

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