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AN APPLICATION OF AIRCRAFT MAINTENANCE SYSTEM DEVELOPMENT BY LEAN THINKING

M.Sc. Thesis by

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UÇAK BAKIM SİSTEMİNİN YALIN DÜŞÜNCE İLE GELİŞTİRİLMESİ VE UYGULANMASI

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PREFACE

Aviation began as a hobby, like so many new and old inventions, flying was considered a fanatic's sport. Definitely aviation has come a long way since 1903, Wilbur and Orville Wright who are known with the first controlled, manned flight. Although, in those early days of aviation, maintenance was performed as necessary, the modern approach to maintenance is more sophisticated. The aircraft are designed for safety and a detailed maintenance program is developed.

The high operational costs in aviation as well as a severe competitive environment, has directed airlines to look for permanent improvements in their management applications at both the planning and operating levels. Conventional cost cutting techniques will not help to fight aggressive policies. Airlines will need to evaluate their process and organizations completely. Lean thinking creates a leap by focusing on eliminating waste, enables companies to decrease cycle times, increase productivity, and improve quality. In this thesis, it is intended to present an aircraft maintenance system development by lean thinking.

This research was supported by Turkish Airlines. I would like to thank the airline staff and Boeing Lean MRO Team for providing the test data and its valuable opinions on this research. I would also like to thank my instructor *Assoc. Prof. Dr. Cengiz Güngör* for his helpful comments and suggestions on the presentation of this study. I would finally thank my husband for supporting me all the time and developing codes for the maintenance planning software and *Enis Ata* for improving software. I would also thank to Deniz Pars for working with me on value stream map. They spent a considerable amount of time on my project.

Jun, 2006 **FERAY GÜNSELİ DEMİRAL**

CONTENTS

ABBREVIATIONS

ACN	: Aircraft Name
ACTS	: Air Canada Technical Services
AD	: Airworthiness Directives
AMO	: Aircraft Maintenance Organization
AOG	: Aircraft on Ground
APU	: Auxiliary Power Units
CE	: Central Engineering
CER	: Component Engine Repair
CIM	: Check Input Meeting
EASA	: European Aviation Safety Agency
EGT	: Exhaust Gas Temperature
EO	: Engineering Order
EOQ	: Economic order quantity
ERP	: Enterprise Resource Planning
FAA	: Federal Aviation Administration
FAR	: Federal Aviation Regulations
HABOM	: International Aviation Maintenance, Repair and Modification Center
IOR	: Immediate Operational Requirement
JIT	: Just in Time
LHT	: Lufthansa Technik
LLP	: Life Limited Parts
MEL	: Minimum Equipment List
MPD	: Maintenance Planning Document
MPN	: Manufacturer's Part Number
MRB	: Maintenance Review Board
MRO	: Maintenance Repair and Overhaul
MSN	: Manufacturer's Serial Number
MTBR	: Mean Time Between Removal
NNVA	: Non Value Adding
NVA	: Non Value Adding
OEM	: Original Equipment Manufacturers
PM	: Production Meeting
PPC	: Production Planning and Control
QEC	: Quick Engine Change
SIAEC	: Singapore Airlines Engineering
SLA	: Service Level Agreements
TAMES	: Turkish Aircraft Maintenance and Engineering System
TAT	: Turn Around Time
THY	: Turkish Airlines
TM&S	: Technical Marketing and Sales
VA	: Value Adding
WPI	: Work Package Index

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AN APPLICATION OF AIRCRAFT MAINTENANCE SYSTEM DEVELOPMENT BY LEAN THINKING

SUMMARY

The high operational costs in aviation as well as a severe competitive environment, has directed airlines to look for permanent improvements in their management applications at both the planning and operating levels. Conventional cost cutting techniques will not help to fight aggressive policies. Airlines will need to evaluate their process and organizations completely. Lean thinking creates a leap by focusing on eliminating waste, enables companies to decrease cycle times, increase productivity, and improve quality.

The purpose of this thesis is to describe how lean thinking principles were used by an aviation company to increase productivity and reduce waste. Existed aircraft maintenance system evaluated, new processes proposed and a new maintenance planning tool presented as a sample of lean thinking. Although significant levels of waste are found, there are many opportunities to eliminate waste from the system.

Many of the recommended function and process improvements are at least partially dependent on a substantial improvement in the IT support to Turkish Technic. This inevitably means that there is a requirement to accomplish extensive software upgrades to the current system or for the replacement of the current system with a new generation fully integrated system in order for these recommended improvements to be fully effective. Moreover, communication needs to be improved between departments and data integrity has to be built.

Finally, this research has shown that the level of appropriate factors has an effect on the planning performance. It is possible to decrease turn around time of line maintenance planning 85%, freeing up 3 hours by lean thinking. If this remedy combined with other departmental improvements, it is possible to save thousands of dollars. The study has presented a model that could be of good benefit to airline operators and other maintenance service organizations. It will enable them to switch their opportunity cost to profit and better meets their demands.

UÇAK BAKIM SİSTEMİNİN YALIN DÜŞÜNCE İLE GELİŞTİRİLMESİ VE UYGULANMASI

ÖZET

Havacılık sektöründeki yüksek operasyonel giderler ve şiddetli rekabet ortamı, havayolu firmalarının hem planlama hem de operasyonel uygulamalarında kalıcı gelişmeler aramasına yol açmıştır. Klasik maliyet kısma yöntemleri, bu politikaya yardımcı olmada yetersiz kalmaktadır. Havayolu firmalarının iş süreçlerini ve organizasyonlarını bütünüyle değerlendirmesi gerekmektedir. Yalın düşünce felsefesi, gereksiz iş süreçlerini ortadan kaldırarak, firmaların iş sürelerini azaltıp, verimliliğin ve kalitenin gelişmesine odaklanır.

Bu tezin amacı, yalın düşünce prensiplerinin bir havayolu şirketinde verimliliğin artmasına ve gereksiz iş süreçlerinin azaltılmasına nasıl katkıda bulunduğunu açıklamaktır. Bu uygulamada, varolan uçak bakım sistemi değerlendirilmiş, yeni prosesler önerilmiş ve yalın düşünce örneği olarak da yeni bir bakım planlama aracı geliştirilmiştir. Çok miktarlarda gereksiz iş süreci bulunmasına rağmen, bunları sistemden gidermek için bir çok fırsat bulunmaktadır.

Önerilen proseslerinin çoğunun gelişmesi bilgi teknolojilerindeki iyileştirmelere bağlıdır. Tavsiye edilen gelişim süreçlerinin tam olarak etkili olabilmesi için ya var olan bilgi sisteminin geliştirilerek güncellenmesi ya da bu sistemin tamamen yeni bir sistemle değiştirilmesi gerekmektedir. Bununla birlikte, departmanlar arası iletişimin ve veri entegrasyonun sağlanması gerekmektedir.

Sonuç olarak, bu çalışma planlama performansını etkileyen bir çok faktör olduğunu göstermiştir. Yalın düşünce felsefesiyle hat bakım planlama zamanı %85 düşürülerek günde 3 saati kurtarmak mümkündür. Bu yeni yaklaşım diğer departmanların katkısıyla desteklendiği takdirde yüz binlerce dolar tasarruf etmek olasıdır. Bu çalışma havayolu operatörlerine ve diğer bakım hizmeti şirketlerine fayda sağlayacak bir model sunmaktadır. Bu model, organizasyonların fırsat maliyetlerini kara dönüştürerek sektörde daha güçlü bir oyuncu olmalarını sağlayacaktır.

1. INTRODUCTION

The high operational costs in air transportation as well as a severe competitive environment, has directed airlines to look for permanent improvements in their management applications at both the planning and operating levels. This tendency has been encouraged by many deregulated countries in recent years. In order to meet their daily agreements, airlines have to assign their aircraft to scheduled or unscheduled flights taking into consideration maintenance and other operational limitations **(Moudani et al, 2000).** Conventional cost cutting techniques will not help to fight aggressive policies. Airlines will need to evaluate their process and organizations completely. Lean thinking creates a leap by focusing on eliminating waste, enables companies to decrease cycle times, increase productivity, and improve quality.

Most researches in airline have only addressed airline processes such as schedule design, crew scheduling, aircraft routing problems. Solving the flight assignment problem has always been a challenging task for the airlines. As a result, it is not surprising that the fleet assignment problem has been extensively studied in the Operations Research literature. Past efforts have seldom focused on the airline maintenance system development and maintenance planning problems by lean thinking. Thus, lean management is a new concept in aviation industry.

The aim of this study is to evaluate an existing aircraft maintenance system by lean thinking, propose new process and present a living sample on maintenance planning. Although significant levels of waste are found, there are many opportunities to eliminate waste from the system.

This study is organized as follows: General information about aviation industry and Maintenance Repair Overhaul (MRO) sector are introduced in Section 2. I then proceed to describe what lean thinking is in Section 3. As a case study Turkish Airlines are discussed. Specifically, the basic problems are introduced in Section 4. Designing a system requires holistic view, so relational departments are observed. Section 5 addresses Production Planning & Control, Engineering, Base and Line Maintenance Departments' current functions and processes in Turkish Technic. Section 6 covers proposed solution approaches. A real application of lean thinking and expected benefits is presented in Section 7. Key performance parameters are offered in Section 8. Finally, Section 9 concludes this study and gives some recommendations for future research directions in this area.

2. AVIATION INDUSTRY

2.1. Aviation in the Beginning

Certainly aviation has come a long way since 1903 when Wilbur and Orville Wright made history at Kill Devil Hills near Kitty Hawk, North Carolina. Likewise, the field of aviation maintenance has made great strides. The early days of aviation were filled with experiments.

At first, aviation was more entertainment than transportation, but soon changed. The technological advances in aviation over ensuring 100 years are impressive. Today, aviation is the safest mode of transport in the world. A considerable part of that safety record can be attributed to the effort of mechanics, technicians and engineers who work in the field of maintenance **(Kinnison, 2004).**

2.2. A brief history of Aviation

Aviation began as a pastime, a sport. Like so many new and old inventions, flying was considered a fanatic’s sport. Through the efforts of people like the Joseph and Jacques Montgofier, Octave Chanute, Otto Lilienthal, Samuel P. Lamgley, Glenn Curtis, Orville and Wilbur Wright, and many others, we have “earned our wings” **(Kinnison, 2004).** We should also talk about Hazerfen Ahmet Çelebi that famous for his flight trial in Turkish history. He flew from Galata to Uskudar for 5 minutes and 51km in 1600 (**Havacılık tarihi**, available at http://tr.wikipedia.org/wiki/Havac%C4%B1l%C4%B1k).

Much work was done by many people, but it was Orville and Wilbur Wright who are recognized with the first controlled, manned flight. Although, they covered a distance of only 120 feet and got no higher than 10 feet off the ground, their first flight was the result of a concentrated effort to master that which other had only courted. Many experimenters in aviation –some of them with more academic or engineering qualifications than the Wrights– had failed to meet the challenges. And some of them, unfortunately, lost their lives in the attempt **(Kinnison, 2004).** Table 2.1 shows significant points in flight development.

Table 2.1: Milestones of Flight **(Milestones of Flight, 2005)**

Artifact	Year	Milestone
Wright 1903 Flyer	**1903**	First successful airplane.
Goddard Rockets	**1926**	First Successful Liquid-Propellant Rocket
Ryan NYP "Spirit of St. Louis"	**1927**	First solo transatlantic flight.
Bell XP-59A Airacomet	**1942**	First American Turbojet
Bell X-1 "Glamorous Glennis"	**1947**	First aircraft to travel the speed of sound.
Sputnik 1	**1957**	First artificial satellite.
Explorer 1	**1958**	First successful United States satellite.
Mariner 2	**1962**	First interplanetary probe.
Mercury "Friendship 7"	**1962**	First American in Earth orbit.
Gemini IV	**1965**	First American spacewalk.
North American X-15	**1967**	First hypersonic, high altitude aircraft.
Apollo 11 Command Module "Columbia"	**1969**	First manned Lunar landing.
Lunar "Touchrock"	**1972**	Apollo 17 Lunar basalt.
Viking Lander	**1976**	First spacecraft to operate on Mars.
Pioneer 10	**1983**	First spacecraft to leave our Solar System.
Pershing-II & SS-20 Missiles	**1987**	First Int'l effort to control nuclear arms.
Breitling Orbiter 3 Gondola	**1999**	First Nonstop Flight Around The World by Balloon
SpaceShipOne	**2004**	First privately developed, piloted vehicle to reach space.

2.3. Promotion of Flying

The world's first scheduled passenger airline service was the St.Petersburg to Tampa Airboat Line, which started operations in January 1914 between two cities, but they carried only one passenger at a time **(Reilly, 1996)**. Service ended after 3 months, however, due to the end of the tourist season and the onset of World War I. During World War I, aviation grew rapidly **(Rainey and Young, 2006).**

It was to be thirty years before leisure air travel was to appeal to anyone but the rich and adventurous. High cost, fear of flying and the absence of toilets in early airliners were the main deterrents; the aircraft of the inter-war years were noisy, slow and not especially comfortable **(Lyth, 2002).** This changed fundamentally after 1958: Airplanes got bigger and flew "higher, faster, and farther" **(Kinnison, 2004)** with the introduction into airline service of the Boeing 707, the Douglas DC-8 and the de Havilland Comet 4. The jet age had arrived **(Lyth, 2002).** Navigational aids both on the ground and in the aircraft, later in earth-orbiting satellites, revolutionized the industry along with drastic improvements' in aircraft and engine technology. Today, 100 years after the Wright Brothers historic first flight, aviation has come of age. People can fly in immense comfort and safety **(Kinnison, 2004).**

2.4. Early Aviation Maintenance

In those early days of aviation, maintenance was performed "as necessary" and the machines often required several hours of maintenance time for every hour of flying time. Major maintenance activities consisted of overhauling nearly everything on the aircraft on a periodic basis **(Kinnison, 2004).**

Before World War II, industry was not very highly mechanical; as a result the impact of down time was not very considerable. Furthermore, equipment was simpler which made it easy to fix, and companies performed mainly Corrective Maintenance. After World War II until the mid 1970's increased mechanization led to more various and multipart equipment. Companies were beginning to rely heavily on this equipment. This dependence led to the concept of Preventive Maintenance **(Asgarpoor and Doghman, 1999).**

In the 1960's, Preventive Maintenance consisted mainly of equipment overhauls done at fixed intervals. Besides, the increased costs of this equipment led management to start finding ways to increase the life of these assets. The latest age started with the aircraft industry in the early to mid 1970's. The giant costs of new highly-mechanized equipment resulted in companies wanting to ensure that equipment lasted and operated correctly for as long as possible **(Asgarpoor and Doghman, 1999).**

The modern approach to maintenance is more sophisticated. The aircraft are designed for safety, airworthiness, and maintainability, and a detailed maintenance program is developed along with every new model aircraft or derivative of an existing model **(Kinnison, 2004).**

2.5. Aviation industry interaction

The aviation industry is unlike any other transportation mode. In aviation, we cannot pull of the road and wait for a truck whenever we have problem **(Kinnison, 2004).** The need for an aviation regulatory authority was recognized in the early 1920's. There have been unsuccessful attempts. After World War II, from 1945 to 1958, the rapid growth of air commerce, aviation technology, and an increasing public demand for air services caused the aviation industry to reach unforeseen levels of complexity. Raised public concern about aviation safety issues and led to the enactment of the Federal Aviation Act in 1958 **(Federal Aviation Administration, 1994).** We are required by Federal Aviation Administration (FAA) regulations to meet all maintenance requirements before releasing a vehicle into service. This is often not the case with other commercial transport mode. The aviation's relationships with differs considerable from that of any other transport mode.

In aviation we have an interactive group of people determined to make aviation safe, efficient, and pleasurable activity. Aircraft manufacturers, makers of onboard equipment and systems, airline operators, industry trade associations, regulatory authorities, flight crews, and maintenance personnel all work together to ensure aviation safety from the design of the aircraft and its systems **(Kinnison, 2004).**

2.6. MRO Business in Aviation Industry

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

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

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

The business of MRO has evolved considerably over the last 40 years and before reviewing the present state, it is worthwhile to briefly review the transformations that have occurred and the drivers of those changes.

2.6.1. MRO Background and Future

Airlines and manufacturers basically concentrated on their own affairs up until the late 1970s. Manufacturers (and there were many) focused on building new models and competing with each other to offer the fast evolving technologies to their airline customers. Fleets enjoyed a relatively short lifespan at the first tier carriers. Post delivery support from Original Equipment Manufacturers ("OEM") was poor.

As a consequence and more of necessity, airlines developed strong in-house capabilities to support their own fleets. Senior executives of the airlines often came from the core technical operations areas. Traditional airlines developed large cost structures to support their fleets and these embryonic MROs were controlled centrally within the airline and were generally inwards facing. Smaller independent airlines came and went but enabled the independent MROs to emerge in the lower tiers of the industry. Figure 2.1 represents MRO industry development.

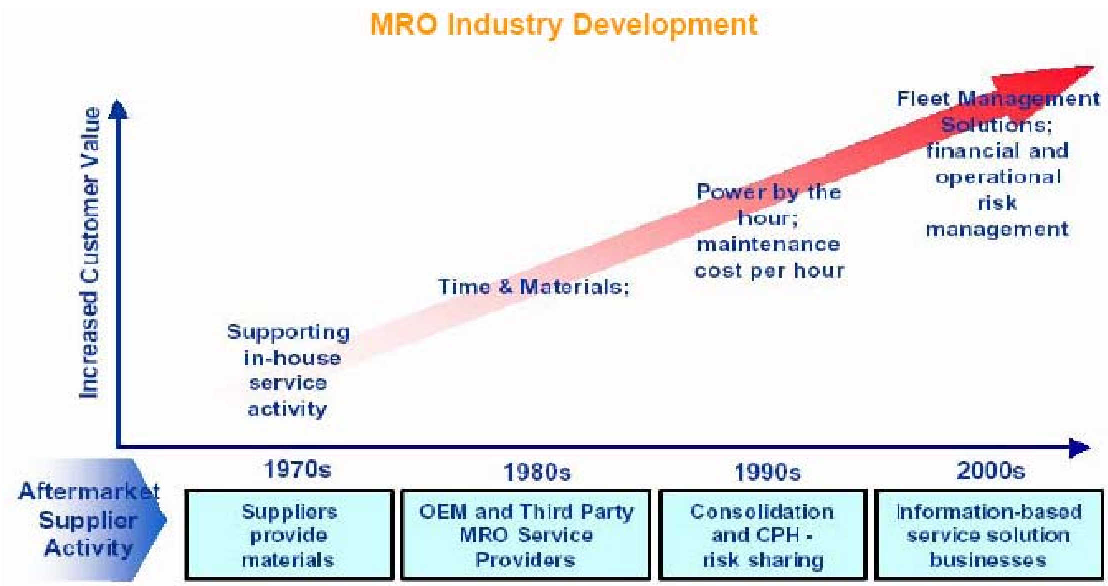


Figure 2.1: The Changes in Component Maintenance in the MRO Supply Chain **(Chrisman, 2005)**

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

- Aircraft, engines and components have become more reliable and have longer service lives (perhaps 20years at first tier airlines)
- Material (parts) consumption declined due to that increased reliability thereby reducing cash flows to the OEMs.
- Technology had increased costs at manufacture and post delivery support. This is reflected in higher launch costs for new types and higher costs for MRO infrastructure.

Today, air transport MRO is a $36 billion market. According to forecasts the market will grow at a compound annual rate of 5.3% through 2013, at which point it will be worth $60 billion a year **(Flint, 2005).**

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

- *Engine Overhaul:* The periodic removal of engines for inspection and overhaul at dedicated maintenance facilities.
- *Heavy Checks*: Major structural inspection of the airframes of aircraft, so that potential airworthiness issues can be identified and rectified before they become problems.
- *Line Maintenance:* Routine maintenance checks performed between flights and during overnight stops.
- *Component – Maintenance:* The repair and overhaul of major aircraft components, including landing gear, avionics and other electrical and mechanical equipment.
- *Major Airframe Modifications:* Major modifications required by manufacturer or caused by aging aircraft. These are also performed at dedicated facilities **(ExelTech Aerospace, 2006).**

2.6.2. The MRO Business

The major airlines have witnessed significant changes in their operating environment after the airline deregulation act of 1978. As a result of fierce competition the airlines had to cut their prices down and this led to more passengers flying than ever before.

More than 80% of passengers are now traveling on tickets priced at less than base fare **(Sriram and Haghani, 2003)**. Air travel in the US has increased from 95 million passengers in 1965 to 547 million passengers in 1995 **(Sachon and Pate´-Cornell, 2000).** This accompanying downward pressure on revenues has led many carriers to focus their attention on controlling maintenance and personnel costs **(Sriram and Haghani, 2003).** The issues of core business focus and economic focus for the airlines are also real but to some extent the impacts of these have been even greater. These competitive pressures on the industry have large implications for the MRO companies.

Airlines were largely the organs of the state and national power and countries often flaunted prestige with little regard to economic performance of those airlines. They were also large workforces and usually above average salaries in these airlines.

Over time and with a gathering momentum many countries have recognized that governments are not best at running economic enterprises. Privatizations of state owned airlines have grown in momentum. These new privately owned airlines are now for the first time subject to commercial pressure and bottom-line focus.

Liberalizations, deregulation and open skies – in the US and EU – are now spreading to other regions. Bilateral Air Service Agreement restrictions are being eliminated, removing important protections from national carriers. Turkey will be subject to such pressure as it moves closer to joining the EU.

The rise of ultra-low-cost MROs will dramatically change the competitive position of MRO providers **(Mercer, 2005).** Low cost carriers have challenged the traditional (high cost) carriers and caused failures of well branded airlines such as: Ansett, Swissair, and Sabena **(Richter, 2001).** The majors have now all adopted some form of low cost carrier to fight on that front. Most carriers have adjusted market offerings to reflect a cost driven commodity market. The free market has seen airlines survive or fail based on their ability to restructure to fit the evolving marketplace.

Severe restructuring of these traditional airlines has seen focus on specific business competencies and a clustering of relationships that are essential to the parent and a distancing of those that are not. Typically support services have been distanced and even made contestable in the market place. Many airlines are looking for insourcing, revenue generating work from outside the company, to reduce their maintenance cost. Airlines with small fleets can achieve a cost savings by outsourcing to larger airlines **(Gatland et al, 1997).**

- Catering services have been outsourced
- Airport handling has been outsourced
- IT has been outsourced
- Operations services have been outsourced

Pressure on the airlines to reduce costs has translated to pressure on suppliers including in-house maintenance departments as well as those independent providers. Increasing trend is the use of maintenance as a source of income. Maintenance has traditionally been a cost center to an airline **(Gatland et al, 1997).** The in-house maintenance departments responded increasingly by restructuring as profit centers or separate business units, to increase the visibility of economic performance and react accordingly to stay competitive.

Maintenance business migrations are increasing to lower cost areas, particularly China, but also the Middle East, Eastern Europe and Ireland etc. Airlines are increasingly interested in reducing their costs by outsourcing to these areas as long as quality, reliability and TAT are *world-class.* The major alliances have been primarily looking at revenue generating to date but increasingly they are now looking at joint initiatives to increase productivity and to reduce costs. Joint purchasing is a Star Alliance initiative. Once part of an alliance even a relatively junior international airline partner can benefit from greater scale, scope and the chance to generate revenue from support work out-sourced by other participants **(Rouse et al, 2002).** Some of the major players such as LH Technik and Singapore Airlines Engineering are building joint ventures or establishing subsidiary operations in low cost regions. This combination of a low cost provider with a powerful brand name is a big threat to other MRO in low cost areas that don't have the brand power.

MRO has now been recognized as a different business from that of the airline and the performance and profitability potential of this area has met with differing forms of treatment by airline leaders. As a brief overview of the developments of plans of a sample of MROs at different stages of development and in different geographic regions the following covers Lufthansa Technik, Singapore Airlines Engineering and TACA in South America.

2.6.2.1. Lufthansa Technik (LHT)

LHT has been a recognized leader in the development of the MRO strategy now being followed globally. It is a separate legal entity yet still has some ties with the workforce in Germany to the airline parent **(Richter, 2004).** The relationship on a business footing is known to be challenging with the airline challenging the pricing structures. It has amassed a wide array of associated businesses providing support to airline operators within the group. The high cost structures in Germany have seen LHT make acquisitions and form joint ventures in some of the lower cost regions of the world. China, Ireland and the Philippines see a substantial LHT presence and little or no airframe heavy maintenance is performed in Germany.

The focus there is on line operations and high yielding modification programs. LHT has a strong repair focus and acts as a competitor to the OEM, often quite aggressively challenging the OEMs on their failure to pursue repairs in lieu of providing new material. LHT has a very strong professional workforce with a very high proportion of graduates. Under the German authority, it now enjoys an automatic approval of its repairs under the FAA. The sell cost of its repaired parts is at a very high margin.

A long time SAP customer, LHT has yet to fully implement the current Aerospace and Defense package, preferring to install modules and interface to older generation systems **(Gillar, 2003).** LHT has reached a critical mass in the aftermarket and enjoys strong support from the parent group. Further expansion is likely, with continued development of focused centers of excellence for airframes. High yielding repairs and component work will continue to return to Germany to feed the LHT factories there **(Lufthansa Technik, 2005).**

2.6.2.2. Singapore Airlines Engineering (SIAEC)

Singapore Airlines Limited is the national airline of Singapore, and the world's second-biggest carrier by market value. It is the leading and founding entity of the Singapore Airlines Group of companies. One of Asia's most influential and successful airlines, it has a presence in most parts of Asia and Oceania, as well as having major operations in Europe and North America (http://en.wikipedia.org/wiki/Singapore_Airlines).

SIAEC is a part of the high technology industry developments pursued by the Government. It is not a truly separate entity and is supported by the government with capital and other incentives. It also has some global subsidiaries, Mobile Alabama being one.

Fleet acquisitions for the airline have seen Singapore engineering able to set up major new business streams with OEM support on the back of large equipment orders. The RR Trent capability is a case in point **(Flint, 2005).**

2.6.2.3. TACA

The TACA group created Aeroman as the group engineering subsidiary based at San Salvador airport. It is basically an airframe facility and has developed from the early 737-200 series through to the classics and now the A320 family. Labour costs are low and Aeroman has attracted work from the USA (Jet Blue) **(Carey and Frangos, 2005).**

2.6.3. The MRO Marketplace and Performance

The MRO business activity is driven by the flying of aircraft and engines. The elements of the business are the management and provision of approved data, trained labour, materials, services and operating infrastructure. An MRO business can contain all of those necessary elements or concentrate only on a small specialized sector of the business.

The other key elements inherent in the MRO business are the regulatory environment and structure; the relationship issues with the OEMs; the constant state of change and developments borne out of a worldwide fleet data sharing for feedback, issues and solutions; together with the more obvious feedback from 'home 'operations and relationships with the airline and operations staffs.

In a similar manner to how the airlines can differentiate between core and non core businesses, so can an MRO business decide which parts it wants to have internally in its structure and which parts it can outsource and acquire service from specialist vendors. There are many permutations but a commonly held view would be that the business performance will drive the outcomes in this regard **(The McGraw-Hill Company, 2005).**

An independent MRO will have a differing view from an MRO emerging from a transforming traditional airline. However the industry is infamous for a high cost base, traceable to the highly regulated cost plus environments of the past. Survival of the MRO customers is increasingly dependent upon those customers having access to the high quality in the widest sense, services yet at the lowest cost. This is a shared drive therefore for both airlines and MROs.

As the MRO industry emerges from the protections of the past, and to an extent the dogmas of the past, we have to support everything that our airline operates being typical, then a management challenge is to constantly benchmark performance and service delivery costs between an internal function and the best in class available from outside. The term *world-class* has come into common usage but in essence that is what a sustainable business must strive to achieve. Practices and performance are constantly changing as aspects of MRO are opened up to existing outside specialized services where that service is the core business of that provider rather than just one of many service functions provided internally by the MRO.

World-class is thus an ever-moving target but it is becoming clear that the eventual structure of an MRO will, like the airlines, be a compilation of service providers, each of whom is world-class, all focused on the ultimate delivery of service to the aircraft in airline service.

Those leaders include:

- Lufthansa Technik ("LHT"). A separate business, but part of the Lufthansa group, which has achieved strategic mass in the aftermarket. A business of over 3,000m$usd revenues, LHT covers a wide range of services on a global basis. Interestingly it has acquired facilities in parts of the world, which have lower cost structures than exist in Germany. LHT executives run these businesses with local management and labour but are focused on introducing the methodologies of LHT **(Lufthansa Technik, 2005).**
- Shannon Aerospace: Originally a joint venture between LHT and SR Technic, now wholly owned by LHT. Focused on narrow body maintenance for LHT and others. (http://www.shannonaerospace.com/SAL_Company/Live/comTemplate.asp?intPage_ID=1)
- Air Livery: A multi national paint specialist with facilities at several sites in Europe **(Air Livery Plc, 2003).**
- Air France Industries: The MRO offshoot of Air France (http://airfranceindustries.airfrance.com/en/toutsurairfrance/3emetier.htm).
- Air Canada Technical Services (ACTS): An emerging MRO player in the Canadian/US marketplace **(Air Canada Technical Services, 2005).**

- EADS/Sogerma: The MRO activity within the Airbus family. (http://www.sogerma.eads.net/site/FO/scripts/siteFO_contenu.php?lang=EN&noeu_id=167)
- SASCO, Singapore Aircraft Maintenance Services: An independent based in Singapore **(ST Aviation Services Co. Pte. Ltd., 2005).**
- Individuals: A range of industry specialists who have current knowledge and have active contracting activities buying services from a range of MRO providers.

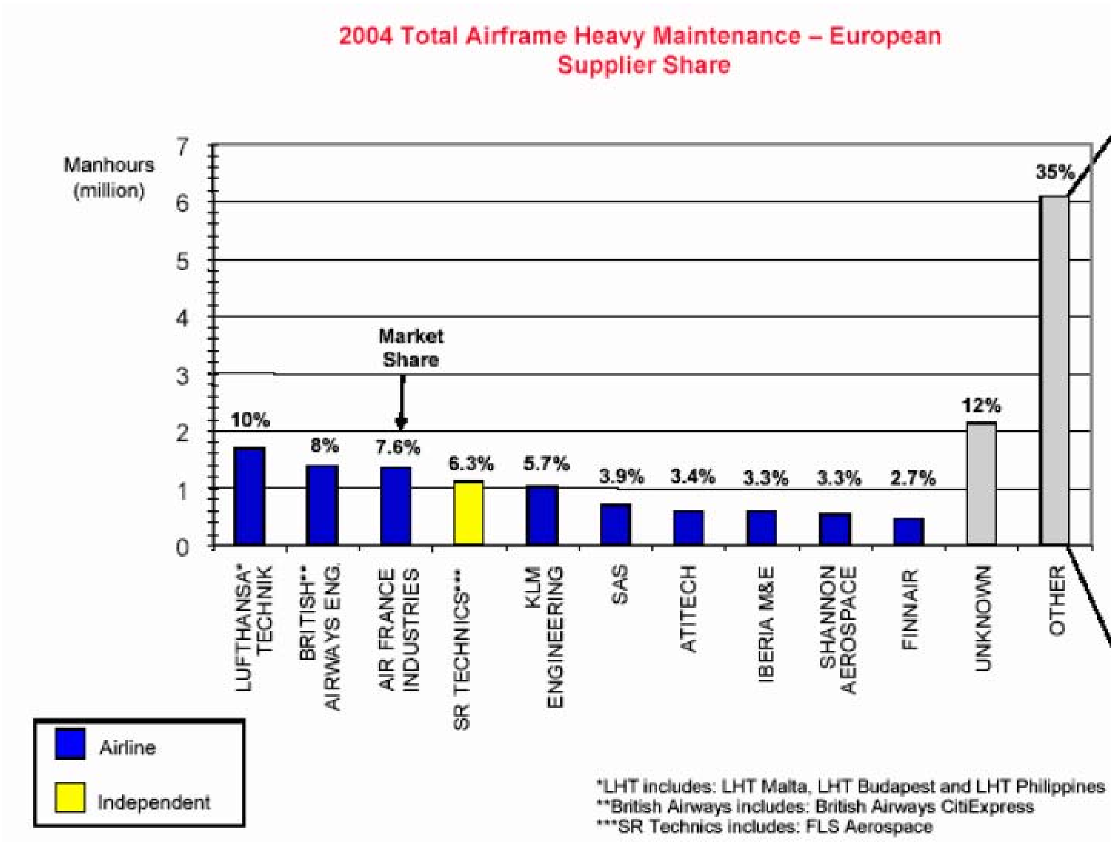


Figure 2.2 : The Graph of Heavy Maintenance Supplier Share **(Stewart, 2005)**

3. LEAN THINKING

The forecasted steady growth of the global MRO market masks significant underlying turbulence as low-cost Asian and Latin American MROs capture increasing market share at the expense of North American MROs. Usual cost cutting methods will not enable them to fight the dramatic wage differentials. Instead, they will need to evaluate their process and organizations completely. “Lean” is a confirmed and generous approach to operational revolution that—by focusing on the customer and eliminating waste—enables companies to simultaneously decrease processing times, increase productivity, and improve quality and reliability **(Mercer Management Consulting, 2005).**

Today’s airline industry is becoming more and more competitive. The price of an airline ticket is about the same as it was 10 years ago. To compete, an airline must continually look for ways to reduce cost as well as generate more revenue and do more without increasing capacity **(Gatland et al, 1997).** As Richard Cobb (1995) says, “For today’s airline maintenance organizations, there is an increased demand for high-quality work and service at low cost”. For MROs willing to take on this challenge, Lean MRO provides a proven set of practices to enable this change **(Mercer Management Consulting, 2005).** Lean thinking provides an approach to become more productive and subsequently more competitive **(Swank, 2003).**

3.1. What is ‘Lean’?

The term “lean” was accepted by three researchers from the Massachusetts Institute of Technology, Cambridge, MA, to describe the production system developed, and carefully applied, by Toyota Motor Corporation which made it such a successful manufacturer **(MRO Software Inc. 2005).** Toyota Production System studied by the number of books and journal articles **(Francis, 2005).** Toyota’s system is centered on continuous improvement and zero tolerance levels for all forms of waste in the manufacturing process, including poor equipment reliability and downtime **(MRO Software Inc. 2005).**

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

Lean thinking is about the removal of waste from the value chain. Waste is defined as any (human) activity which absorbs resources but creates no value. This definition includes mistakes which require rectification, production of items no one wants and processing steps which aren't actually needed. Companies waste vast amount of time, naturally they waste a lot of human effort **(Caulkin, 2002).** Lean thinking provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more effectively **(MRO Software Inc. 2005).** It is 'lean' because Japanese business methods used less of everything – human effort, capital investment, facilities, inventories and time – in manufacturing, product development, parts supply and customer relations **(Ikovenko and Bradley, 2004).**

Lean techniques cut costs by eliminating waste—those items and process steps the customer doesn't value. These reductions paradoxically increase quality as production problems become more visible and root causes more easily identified and remedied in simplified work processes. The approach increases throughput dramatically by a focus on single-piece continuous flow and a flexible structure of cellular product-family work teams. Since flow starts with the pull of actual customer demand, overproduction is essentially eliminated. Inventory levels are reduced and turns increased through the combination of just-in-time (JIT) and kanban **(Ikovenko and Bradley, 2004) (Bruun and Mefford, 2002).** As a result, Lean significantly reduces working capital requirements. Fixed assets are managed more efficiently through the application of Total Productive Maintenance and revamped accounting systems that seek to measure value in the eyes of the customer. In addition, a by-product of Lean is more available floor space, freeing additional capacity to support a more aggressive sales effort **(Mercer Management Consulting, 2005).**

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

3.2. The principles of lean thinking

The five principles of lean thinking presented in Figure 3.1 **(Womack and Jones, 1996).**

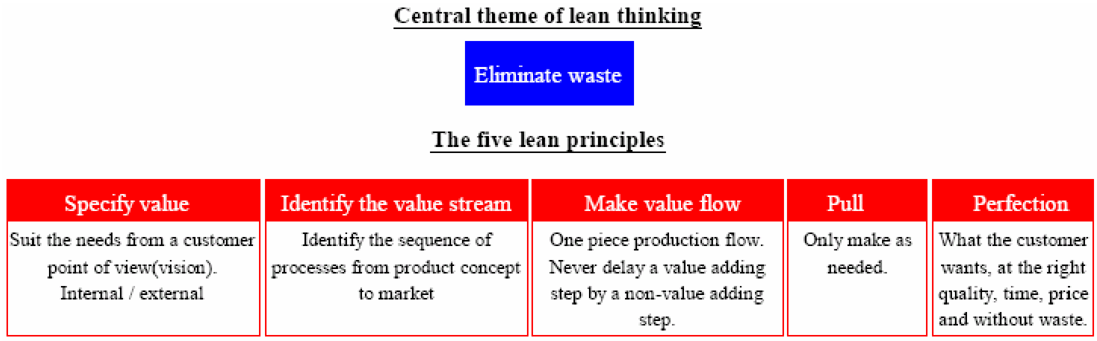


Figure 3.1 : Theme and principles of lean thinking **(Davies and Greenough, 2006)**

3.2.1. Value

The critical starting point for lean thinking is value **(MRO Software Inc, 2005).** Value deals with the value we provide to our customers. Value is the complete package of products and services we use to serve our customers and penetrate the market from the point of view of the customer. In line with a target costing approach, this value translates into the price the customer is willing to pay and, in turn, to the product and service costs we must achieve in order to satisfy the customer and the company's stakeholders **(Maskell and Bruce, 2006).** A general estimate for a typical manufacturing firm is that value adding accounts for less than 5% of the total time; accordingly remaining 95% of the time is spent adding costs such as storage, transportation and delaying **(Bradley and Ikovenko, 2004).**

To develop breakthroughs with lean thinking, the first step is learning to see waste. If something does not directly add value, it is waste. If there is a way to do without it, it is waste. Taiichi Ohno, the mastermind of the Toyota Production System, identified seven types of manufacturing waste **(Poppendieck, 2002).**

The Seven Wastes of Manufacturing:

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

Non-value-added activities are those activities that aren't required but still occur. Anything that adds unnecessary time, effort, or cost is considered non value-added and may be defined as waste. To put it another way, waste is any material or activity for which the customer is not willing to pay. For example, testing and inspecting are obvious areas of nonvalue- added activities. Customers expect the product or service to be correct; they don't care whether you consumed a day or week in getting it right as long as it performs as promised. A process is also identified as non-value-added if the step in the process does not change the output in terms of form, fit, or function.

Value-enabling activities don't add direct value for the customer, but they are necessary. For example, government regulations don't add direct value but you must comply with them to stay in business. The figure 3.2 shows the process of waste elimination **(Kullmann, 2004).**

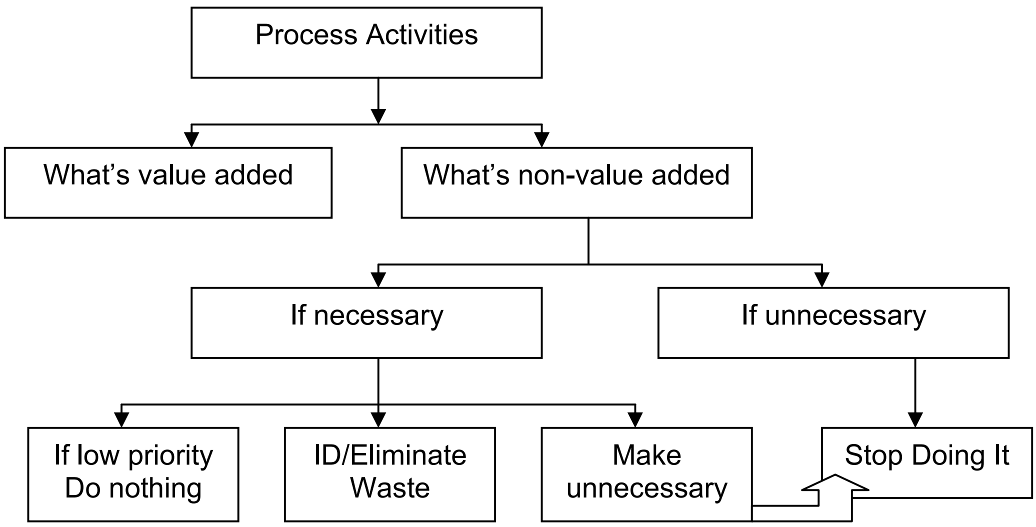


Figure 3.2 : The process of waste elimination **(Boeing, 2006)**

3.2.2. Value stream

The traditional key technique behind the value stream is that of process mapping to understand how value built into the product from the point of the client **(Bradley and Ikovenko, 2004).** Value stream recognizes that the company's processes create excellence and customer-driven performance. Traditional departmental control structures run counter to lean thinking. We must understand, control, and manage our business through the processes, or value streams, of the organization **(Maskell and Bruce, 2006).** The value stream is the set of all the specific actions required to bring a product through the three critical management tasks of any business:

1. Problem-solving task, running from concept through detailed design and engineering to production launch;
2. The information management task, running from order taking through detailed scheduling to delivery; and
3. The physical transformation task, proceeding from raw materials to a finished product in the hands of the customer **(MRO Software Inc, 2005).**

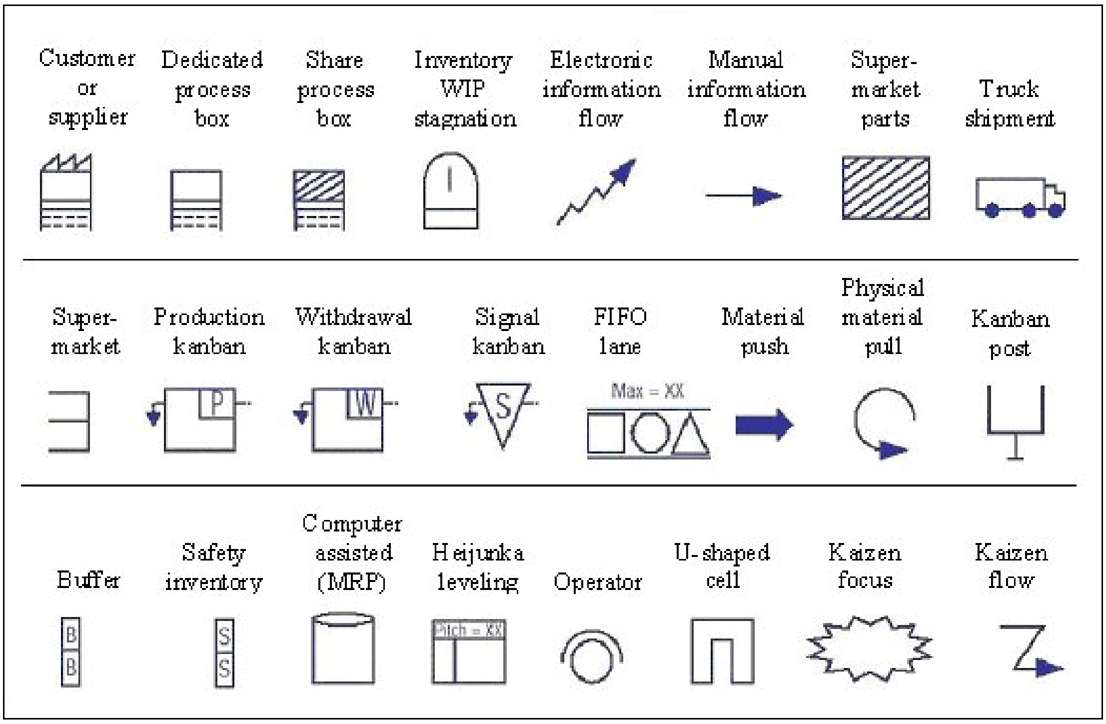


Figure 3.3 : Value Stream Map icons **(Grout, 2006)**

Multiple flows can be represented using value stream mapping. The icons include manual and electronic information flows, material “push” (schedule driven) flows, and material “pull” (demand driven) flows **(Grout, 2006).**
Documenting the value stream is precisely mapping the set and sequence of all specific actions, communications, and material movement required to bring a product or service, valued by the customer, from conception to final delivery. The aim of values stream map is recognizing the waste. Mapping the value stream enables you to identify valued-adding and non-value-adding activities from the customer’s perspective. Any activity that doesn’t add value for the customer is waste and offers an opportunity for improvement **(Kullmann, 2006).**

3.2.3. Flow

The ideas of flow embraced by "leaners" have their roots in the Toyota Production System **(Maskell and Bruce, 2006).** Flow is defined as producing a product from raw material to completion without unnecessary interruption or delay **(Bradley and Ikovenko, 2004).** Anything that interrupts the flow of products and services through the value stream is designated as muda – or waste **(Maskell and Bruce, 2006).** Once value has been specified, the value stream for a product fully mapped, and obviously wasteful steps eliminated, it’s time for the next step — make the remaining value-creating steps flow. Instead of having activities performed by distinctive departments, all of the activities pertaining to the completion of a product or service should be organized in a single, uninterrupted flow **(MRO Software Inc, 2005).**

Ensure the uninterrupted movement of material through a process without backflow or scrap, one piece at a time. Continuous flow yields shorter cycle times and, shorter lead times; and it allows production flexibility, higher throughput, and increased revenue. it’s a value stream – make it flow smoothly **(Kullmann, 2004).**

3.2.4. Pull

This principle derives from Toyota’s innovation, the Kanban **(Bradley and Ikovenko, 2004).** Once a company has placed its revenue generating assets in a flow concept, the next step is to make the product only when there is actual demand from a customer, instead of working against a forecast **(MRO Software Inc, 2005).**

Pull is an important mechanism to enable flow of the products and services. Nothing should be "pushed" through production or service processes. Everything is "pulled" based upon the customer’s real demand and requirement. Again this is based upon the Toyota Production Systems that puts great emphasis on "pull"` and the use of kanban (or other visual methods) to facilitate a pull approach. If this approach is employed throughout an organization there will be very little inventory because the organization will make only what the customer is immediately "pulling" in terms of demand upon the production plant **(Maskell and Bruce, 2006).**

3.2.5. Perfection

After an improvement has been made, it must become the standard for the process. It is important to understand that transformation to Lean is a continuous process **(Bradley and Ikovenko, 2004).** Once companies have implemented all of the above lean principles, it often dawns on those involved that there is no end to the process of reducing effort, time, space, cost and mistakes while offering a product which is ever more close to what the customer actually wants. Striving for perfection can drive additional rounds of improvement **(MRO Software Inc, 2005).**

Perfection within lean thinking has two elements. The first is the classic TQM understanding of quality improvement. Lean manufacturers use both continuous improvement (kaizen) and breakthrough improvement to make on-going and substantial change in their operations. This is how lean organizations pursue excellence in both the short term and the long term **(Maskell and Bruce, 2006).**

3.3. Key Tools of Lean

Lean employs a variety of tools to put those principles into practice. Some representative examples include:

3.3.1. 5S

5S specifies rules for cleaning and organizing the workplace so that each worker’s work area is laid out and maintained for maximum efficiency **(Kullmann, 2004).** A clean and well-maintained factory can help you delay or avoid the need for a larger facility since you can gain 15% additional free space after implementing 5S.

The 5S pillars:

- **Sort:** The first step of 5S involves getting rid of rubbish and clutter. Applying 5S to an office environment would include removing files and papers that have no use in the near future (often things you sort through on a daily basis wasting time doing so in the process) **(DVRIC, 2003).**
- **Straighten:** This phase of 5S is all about keeping things in their rightful place. Tools are put where they are needed, often utilizing shadow boards thereby making sure they are to hand and labeled as they should be **(DVRIC, 2003).**
- **Sweep:** Once the rubbish has been disposed of and everything has been given its proper place, this phase of 5S is all about maintaining the newly found order **(Institute of aerospace excellence, 2003).**
- **Standardize:** You could sum up this phase of 5S as "Maintaining routine". Once the workplace has got through the first three phases it is often difficult to keep it up to the new standards you have set yourself **(Institute of aerospace excellence, 2003).**
- **Sustain:** This step of moving into the area of "Kaizen" or ongoing improvement. All the previous steps of 5S have been about creating and maintaining a clean and tidy working environment. This phase of 5S is about moving forward not just maintaining the standards you've set yourself but building on those and raising the bar **(Institute of aerospace excellence, 2003).**

3.3.2. Production leveling

Production leveling smoothes production by distributing volumes and product mix as evenly as possible over time in order to avoid disruptive peaks and valleys **(Kullmann, 2004).**

3.3.3. Poka-yoke

Poka-yoke enables the enforcement of quality at the source by providing methods of mistake-proofing through in-line quality testing of 100 percent of the units in the process **(Kullmann, 2004).**

3.3.4. Kaizen

Kaizen means breaking apart the current situation, analyzing it, and quickly putting it back together to make it better **(Gemba, 2002).** Kaizen circles and Kaizen events increase worker involvement and effectiveness by bringing together small groups of workers to generate ideas for solving problems and improving processes, thus helping fulfill the ongoing goal of continuous improvement **(Kullmann, 2004).**

3.3.5. Work Cells

Work cells, often laid out in a U-shape bring together several stages of a process in order to eliminate transport waste and waiting, to facilitate one-piece or small-batch flow of products through the process, and to take advantage of multi-purpose workers who can perform any process handled by the cell **(Kullmann, 2004).**

4. TURKISH AIRLINES OUTLOOK

4.1. THY - The Airline

Turkish Airlines was established on May 20, 1933 as the State Airlines Administration working as a department of the Ministry of Defense. In 1935, it was transferred to the Ministry of Public Works; in 1938, it became the State Airlines General Directorate; as of 1939, it began to operate as a department of the Ministry of Transportation. In 1955, it was restructured as a private company subject to private law. From then on, it operated under the name of Turkish Airlines, Inc. **(Turkish Airlines, 2004).**

Turkey as a nation is embarked on a path to join the EC and although the timescale for this transition is counted in many years the country and the industries in Turkey will have to make adjustments and changes necessary to fit the EU criteria. The airline is government owned and is run as a state enterprise. To a significant extent this sees THY required to conform to practices and procedures which have typical characteristics of a state controlled bureaucracy.

Government support to a state owned airline enterprise within the EU is not an option. Kotil does not believe the likely accession of Turkey into the EU will affect THY negatively. Moreover, he thinks the airline is well positioned to compete with EU carriers. "We are increasing our service levels while lowering our operating cost. We have about the lowest cost of all AEA member airlines" **(Buyck, 2005).** Competitive market forces will demand a business culture and bottom line focused organization. The drive to cost reduction and to achieving *world class* levels of achievement will be found to apply to THY.

Airlines can already see the European and world carriers transforming themselves rapidly into new shapes and organizations within an aggressively competitive market place. This is therefore an opportune time for strategizing and transform themselves using the industry learning that are available and which can enable THY to play catch up without necessarily making the mistakes these other carriers have made in their transformations.

The HABOM (International Aviation Maintenance, Repair and Modification Center) Project will be established by THY, at the Sabiha Gökçen International Airport at Kurtköy, Istanbul. Construction work under the HABOM Project has been scheduled for the beginning of 2005 **(Buyck, 2005).** The project is expected to be completed and the facilities launched by 2007. A total of US$ 200 million will be invested in the project, construction and equipment work included. The State Planning Organization has allocated US$ 50 million for the project in 2005 **(Turkish Airlines, 2004).**

This should all be put in context to signal some of the further potential changes such as may impact on the interface with Government and in detail the corporate changes required and the possible changes for the airline and the operating departments of catering, airport handling, cargo, training etc as operating entities. In this respect there appears to be a clear and pressing need to introduce financial tools into the operation as a necessary precursor to a move to de-centralization. The implications on the corporate service functions of Human Resources, IT and systems, Finance and indeed the airline structure itself need to be explored as the strategy unfolds.

4.2. THY Technic - In Transition

A rapid transition to a stand along operating subsidiary is an unlikely achievement. However there are strategies which if applied could see the timeframe optimized, particularly if transitions can be managed in parallel projects. The fundamental steps along the way would include:

- Introduction of clear interfaces with the other operating departments of the airline.
- Introduction of a business focus into Technic perhaps by becoming a profit centre with embedded business units each operating as a business with operating balance sheets and profit and loss accounts.
- Development of Technic into a world class organisation and MRO provider delivering world class service and products.
- Growing the third party business and achieving a regional reputation for service which will grow the business and enhance and encourage potential joint venture and other equity opportunities.

4.3. THY Technic - The Current State at an Overall Level

4.3.1. IT Systems

The current crisis in the aviation industry has focused minds on the need to maximize operational efficiency. Aircraft Technology explores the IT products that are available to airlines, OEMs and MRO providers seeking to streamline their maintenance operations **(Delia Systems, 2002).**

THY Technic has a series of legacy systems built around1980. IT system acquired from USAir, an integrated maintenance system, which in fact is an earlier version of products it markets to the other carriers, Merlin and Maxi Merlin **(Peck et al, 1998).** This system can no longer be called Merlin as it has been locally modified and interfaced and is now a stand alone application with no vendor support. Certain modules acquired at the time of purchase remain inactive and are most likely difficult to implement now with the scale of changes made to the basic system. The system is known as Turkish Aircraft Maintenance and Engineering System ("TAMES"). Surrounding this system are several PC based applications and developments and other packages for specific functions. Many, of these applications are stand-alone and not networked.

In reality the systems offer lack the functionality required for MRO operations in 2005 and beyond, and are fast becoming unsupportable with consequent severe impact on organizational performance. The ERP systems are the next layer that consists of the Asset, Document, and *Workflow Management System*. The *Asset Management System* provides access to all information related to the physical objects such as toolboxes, tools and parts. The *Document Management System* stores the electronic versions of the MRBs (Maintenance Review Boards) and any other forms or documents that are needed for the MRO process such as the MPDs (Maintenance Planning Document). MPD describes the MRO tasks and for each task the necessary activities. MRB describes maintenance procedures for different parts. Digital signatures can be attached to all documents **(Lampe et al, 2004).**

THY Technic have recognized this deficiency and studied the opportunities that would flow from the adoption of a current generation ERP system such as the SAP Aerospace and Defense System. Complementing mySAP PLM are solutions from SAP for Aerospace & Defense. These include basics for line maintenance; maintenance, repair, and overhaul (MRO); and component/engine repair (CER) – all helpful for organizations that operate, maintain, and support complex technical assets such as aircraft, ships, and land-based systems **(Sap Group, 2004).**

Good data is a prerequisite for the performance measurement and management processes that will be part of the future state. What performance measures that are in use are made suspect by this basic data integrity and also any financial visibility. Accessing the data is another issue.

Data integrity is a key concern because with an ERP system (no different as for any computer system) the benefits can only be realized if the correct data is captured at point of entry. Equally *data integrity is a key regulatory compliance issue* for the aviation authorities and also a key part of the asset value management that provides for the aircraft and engines of its customers **(Arena Solutions, 2005).** The ERP installation will further influence the functionality as the essence of the system is to see data entered once only, yet made available to everybody who needs to have access to it **(United States Government Accountability Office, 2005).**

ERP introduction will bring a much wider application of computers around the shop floor and in the workshop areas. Much of the cost benefit of installing such a system will come from the enabling technologies such as bar coding and a general move to discourage paperwork. This movement is gaining momentum across the industry as the availability of web based data increases. Updated IT will improve maintenance productivity by 10% and reduce inventory by 30% **(Moorman, 2004).** The high costs of the legacy systems of hardcopy, microfilm, and even CDroms will mean these data solutions will disappear quite quickly. The eventual ERP project will have some major cost components beyond simply the package acquisition. These will include a huge investment in hardware and training. ERP is an all or nothing future if the benefits are to be released.

According to Francis (2005), there are some Indicators of Information Waste. In this perspective waste in IT systems of can be summarized as below:

- Long, unpredictable processing lead times.
- Presence of bottleneck departments.
- Lack of consensus regarding priority.
- Multiple iterations (of unpredictable duration) for problem resolution.

- Proliferation of validation checks, and validation of the validation checks!
- Lack of standard work practice and disparate routing.
- Multiple, uncontrolled document copies in simultaneous circulation.
- Presence of unofficial and/or uncontrolled expedite path (fastrack).
- Batching of documents.
- Ineffective (or non existent) workload scheduling.
- Multiple, departmental computer applications for project tracking.
- High levels of data entry errors and rekeying.
- Production of reports which nobody uses.

4.3.2. Management & Supervision Issues

The essence of a high performing organisation is the existence of high performing teams working together towards common goals. Thus, the major factors contributing to the concept of a team are shared goals, the interdependence of their actions, and the division of labor in terms of established responsibilities for meeting those goals **(Endsley and Robertson, 2000).** This overarching philosophy needs to be implanted into the organization by the management and supervision practicing this visibly at every opportunity.

These matters can be mitigated at this point and changes towards a more seamless vertical organization can be made with benefits that will grow by eliminating those vertical disconnects.

4.3.3. Business Disciplines

The MRO sector of the aviation industry demands an underlying set of disciplines perhaps unlike many similar industries. Aviation is a safety driven industry and MRO and Flight Operations are two of the key functions in this respect. Aircraft maintenance system is a complex one with many interrelated human and machine components **(Federal Aviation Administration Office of Aviation Medicine, 1991).** To ensure quality, federal aviation regulations (FARs), industry and federal policies, and approved corporate policies and procedures specifically control the work performed on an aircraft **(Krausa and Gramopadhyeb, 2001).** Unfortunately, though, maintenance and aircrew related aircraft accidents still occur. Though 75% of aircraft accidents are classified as either pilot or human error, a recent study concluded that 18% of all accidents are maintenance related **(Krausa and Gramopadhyeb, 2001).**

This has lead to some sector dogmas which might usefully be explored as helping the organizational transition.

- All work on an aircraft must be documented and traceable to the individual performing the work.
- There must be separation between those specifying the work to be done, those doing the work, and those keeping the record of the work performed.
- There must be an independent quality oversight of work done in all areas of the MRO.

The MRO sector also can see the application of more general dogmas such as:

- Maximum productivity is achieved by keeping the worker on the task and ensuring that the task is not commenced without all the necessary resources being at hand.
- Accountability and performance measurement will enhance performance
- Empowerment and delegation follow training and demonstration of skills
- Planning is continuous process from strategic planning to production planning of a project.
- An organisation should make a single function accountable for specifying what the company requires to be done. No other part of the organisation can make a change to that scope of work and all variations must revert to the accountable party for the variation to be approved **(Pan American Health Organization World Health Organization, 2006).**

These dogmas need to be embodied into the culture. A better understanding of the organization will surely help people to know their own roles in it. This means that management and supervision have to buy into and support these dogmas and practices in order to help the organization work effectively.

"Every enterprise is a learning and teaching institution. Training and development must be built into it on all levels – training and development that never stop" **(Garvin, 1993).**

The leadership has to enforce these disciplines so that they are inculcated into the way the organization works. Enforcement in this regard is not a penalizing measure rather it is a continual reinforcement of the need for the disciplines. Disciplines need to be lead, and the organizational functionality and role definitions understood on the basis of how each contribute to the effective running of the whole team.

“Learning is at the heart of a company’s ability to adapt to rapidly changing environment” **(Prokesch, 1995).**

Management training is less about the attainment of qualifications and more about the understanding and development of interpersonal skills and the needs individuals have. Applying these understandings enables leaders to think and act as leaders whilst the work is delivered by the staffs that understand and relish the way in which the organization treats them as people. Teams come together in the work environment to achieve outcomes and the sensitivity to team member’s position in the external society and power plays has to be eliminated **(Deiss, 1996).**

4.3.4. Communication

In addition to the need for being a team, a significant task for maintenance crews is the coordination of activities and provision of information across teams to those on different shifts. For instance, an Eastern Airlines aircraft nearly crashed when oil pressure was lost to all engines almost at the same time due to a maintenance error in servicing the engines in which critical o-rings were left off **(Washington DC, 1983).** This problem has been directly linked to a problem with coordination of information across shifts and between maintenance departments **(Endsley and Robertson, 2000).**

Communication is a key area where the leadership can influence the performance of the people and hence the organization greatly. Open, honest and appropriate communication is a key leadership responsibility and should occur through a range of channels and at all levels of leadership. Communication in any large organization is a difficult and challenging management function. At the very basic level it has to satisfy and provide timely understanding to people as to why certain things are happening and often also relieve fears or provide direction and guidance to people affected by change.

Communication needs to be tailored to the understanding and interests of the recipient. Communication as a tool can be used by effective leaders to build harmony and common purpose into the organization. It starts from the leadership and is exercised through meetings and briefings. It cascades down the organization and as it does so risks being changed in intent and meaning. It can be reinforced by mass briefings on significant issues, and also by in-house regular publications.

5. FUNCTIONS AND PROCESSES IN MRO

5.1. Production Planning and Control (PPC)

Production planning and control (PP&C) is one of the key organizations within MRO. It is the heart of the maintenance organization. The PP&C organization is primarily responsible for planning and scheduling all aircraft maintenance activity within the airline.

Actually PP&C has three primary functions: forecasting, planning and control. Forecasting activities include the estimated maintenance workload for the long term and the term based on the existing fleet and business plans and on any known changes in these for the forecast period. Planning involves the scheduling of upcoming maintenance and includes the planning and scheduling of all manpower, parts, facilities, and time frame requirements for such maintenance: less than A check items, daily check, 48 hour checks, transit checks, and letter check such as A, B and C **(Kinnison, 2004).**

Production Planning and Control Department in Turkish Technic is responsible for the functions of:

- Aircraft Input Planning and Scheduling
- Production of Input Work Packages
- Materials Planning for Aircraft, Engines and Components

5.1.1. Aircraft Maintenance Plans

The development of aircraft maintenance schedule is a complicated task involving the synthesis of a range of economic, legal and technical factors. Demand for service, aircraft utilization and operational cost of aircraft are the principal drivers. The goal is to achieve a balanced pattern of flights that results in a timetable consistent with the FAA regulations and airline policies **(Sriram and Haghani, 2003).**

The success of an airline depends on the quality of its resource planning and control processes. Planning is aimed at extracting the highest possible usage from the available resources. It is a challenging task. Profitability depends not only on filling seats and maximizing revenue per passenger, but also on slot utilization, turnaround times, code share arrangements and the mix of equipment and resources used. Airline network planning is based on a detailed analysis of passenger. This includes the optimization of timings, connectivity and capacity assignment. Planning requires maximum flexibility in adapting all airline resources, to make a compelling offer and satisfy demand in an intensely dynamic market – and thus maximize revenue **(Lufthansa Systems, 2006).**

The airline planning process is normally divided into several steps. The common procedure is to first create the timetable, then plan fleet assignments. Tail Assignment, on the other hand, is the problem of deciding which individual aircraft (identified by its tail number) should cover which flight. The main focus of Tail Assignment is the ability to operate the schedule, and it thus deals with individual aircraft and the actual operational constraints that must be fulfilled. The most important of the operational constraints, apart from simple things such as minimum connection times, are maintenance constraints—each aircraft must get maintenance of different types with regular intervals. Maintenance regulations are often decided by national agencies. The airlines often have their own internal rules, which are slightly harder than the national rules, to make solutions more robust in case of disruptions. Most maintenance checks are not fixed in time initially, but should be placed where necessary. Others are planned in advance. There are also other operational constraints, such as destination restrictions, specifying that certain aircraft are prohibited from flying to certain airports, possibly at certain times. Often, different restrictions exit even within a certain fleet of aircraft, e.g., due to differing in-flight equipment, engine, or country of registration. It is thus crucial to consider individual aircraft to ensure that the restrictions are followed **(Mattias Grönkvist, Article in Press).**

From an operating point of view, the demand for service sets the daily flight schedule and determines which type of aircraft will be flown on a given route. This is the primary constraint faced by the maintenance planners who must schedule inspection for each plane in the fleet in compliance with the FAA regulations. The possibility of assigning individual aircraft to different routes throughout the day offers the flexibility needed to meet this requirement **(Sriram and Haghani, 2003).** During the route planning process, the maintenance status of the individual aircraft is unknown as well as their next scheduled maintenance checks. This makes planning process difficult **(Belanger et al, 2005).**

There are three programs used in planning activities in THY. TAMES is the basic database program used in all activities. Beside this, Turkish Airlines has been using the Lufthansa Systems portfolio for network planning and control - NetLine/Sched (schedule management) and NetLine/Ops (operations control) - since 2001.

The integrated NetLine product line from Lufthansa Systems is one the world's leading software solutions for the airline industry. Implemented by more than 40 airlines worldwide, NetLine has gained a reputation as a solution that is characterized by a high degree of efficiency, and user-friendliness **(Lufthansa Systems, 2004).**

NetLine/Sched is an interface with Commercial department to agree the scheduled maintenance de-scheduling requirements in terms of slots by elapsed times and days of the week. This is an iterative negotiation resulting in the agreed input slots being included in the 'NetLine Sched'. Planned flights and maintenance slots exist in Sched. There is no aircraft name in Sched, only aircraft name can be seen. Orange boxes show maintenance slots and blue boxes show flights.

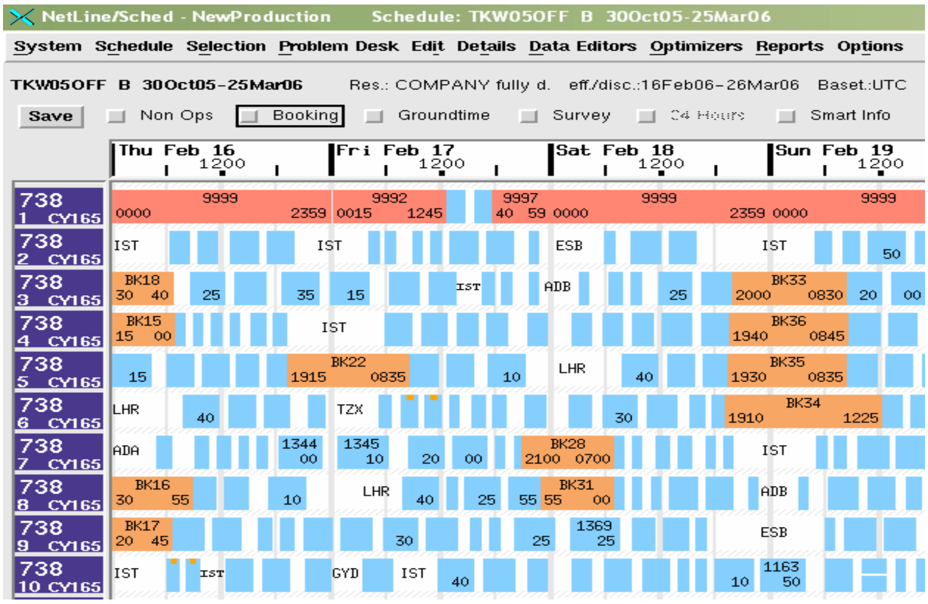


Figure 5.1 : The view of NetLine/Sched

Flights are assigned to the aircrafts in "NetLine/Ops" Operations Control aircraft planning system. Blue boxes show planned flight, grey boxes show realized flights. Brown boxes are PPC's maintenance slots or aircraft failures.

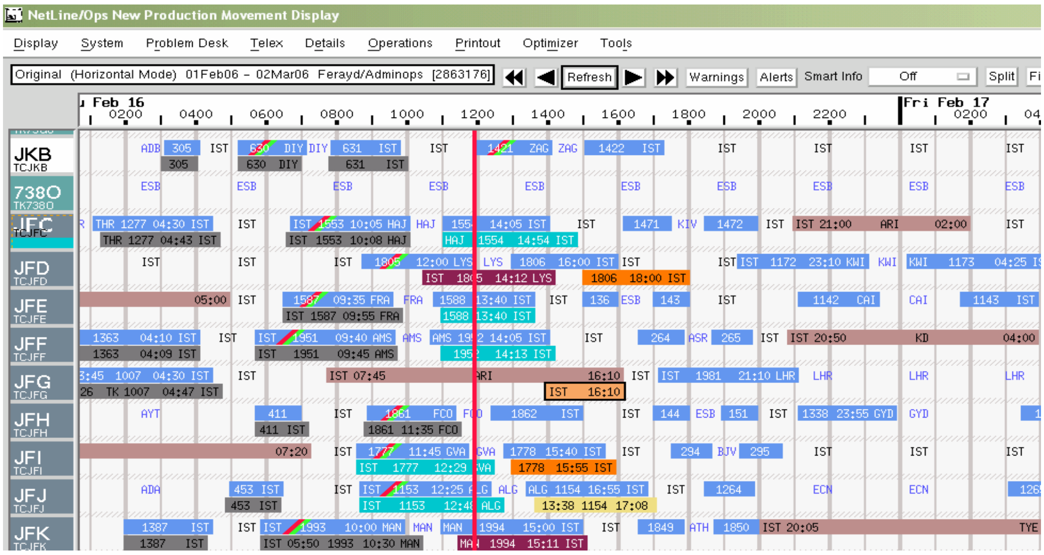


Figure 5.2: The view of NetLine/Ops

The table below shows the relation NetLine/Ops and NetLine/Sched process. There is a day limitation in both of these programs. The last 3 days is under Ops control. All the other activities reflected from Sched to Ops.

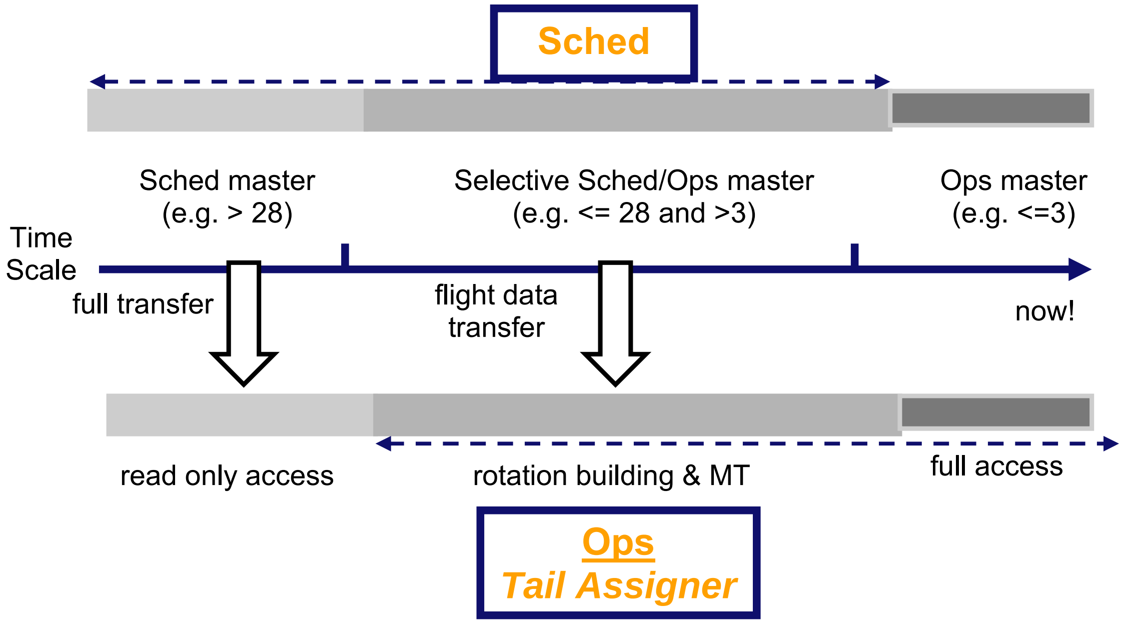


Figure 5.3: The relationship between Ops and Sched **(Piotrowski, 2002)**

5.1.2. Long-Term Capacity and Maintenance Plans

The long-term maintenance plan is the most sophisticated and requires detailed checks and related maintenance throughout the aircraft. Level C and level D maintenance checks are usually classified as long-term maintenance. The long-term plan usually takes 10 days or more and is usually performed at an airline's base airport **(Yan et al, 2004).** In THY Technic all wide-body aircraft operation and narrow-body C and D checks are classified as long-term (base) maintenance.

The longest planning timeframe currently formalized is a one-year period. There is no five-year long-term plan created to highlight resource constraints, which may take in excess of one year to correct, such as additional hangar facilities, additional staff, i.e. a capacity plan.

There is a dialogue held between Production Planning and Commercial Department to develop a forward plan of long downtime check input dates and elapsed times based on ultimate check periodicity within the constraints of the requirements of the operational plan. This uses a simplistic three-year forward plan drawn in Excel.

5.1.2.1. One-Year Plan

The One-Year Plan is the longest formal planning horizon. It is created for a rolling 12-month period and is reissued on a 2-monthly basis officially; however, this timeframe may become quarterly in practice.

Production Planning takes TAMES data and creates this plan using a semi manual process based in Excel. Landing Gear expiry data is provided from Materials Planning group. Third party work is added to the plan as it becomes contracted.

The plan contains the following data:

- Heavy maintenance check inputs, by type, registration.
- Planned input and output dates for each event (Turn Around Time – TAT)
- Brief reference to check type/content and operator (for third party work)
- Staff by trade, by individual aircraft, showing actual requirement, planned total available and excess or shortfall in manpower.
- Takes account of primary leave periods, movements to Line Maintenance for summer peak and known training impacts on available staff.

In terms of both man-hours and elapsed downtime required to accomplish each check, the standards used are based on past actual achievement.

The plan does not contain the following data:

- Line ‘A’ check aircraft
- Aircraft check expiry hours/cycles/date.
- Engine changes
- Landing Gear changes
- Aircraft inputs by hangar bay
- Visual chart of labour requirement against available to immediately highlight labour shortfalls.

5.1.2.2. One-Month Plan

The one-month plan is an extract from the one-year plan and effectively replicates the same data but is updated and reissued weekly. The plan is created through a semi-manual process based in Excel. The plan contains the same basic data as the one-year plan but also includes engine change data. It also, therefore, contains the same basic shortcoming in terms of the man-hour and elapsed time standards used which are based on past actual achievements.

The engine change data is provided to Production Planning from two sources. Engine LLP expiry data is provided from Engine Materials Planning group (within PPC) and estimated performance deterioration related engine removal data is provided from Powerplant Engineering.

5.1.3. Short-term (Light Maintenance) Plan

The short-term maintenance plan, which is also called light maintenance plan, is usually performed at the airport gates. Short-term maintenance can usually performed in a night shift. The maintenance tasks are performed before departure and/or after arrival, therefore, timetable and time constraints have to be met, otherwise, flight delays as well as extra operation costs could be incurred. In general, short-term layover maintenance includes three types of jobs, pre-flight checks, transit checks, and daily checks. The preflight check is a regular procedure performed prior to each take-off. It has to be finished by the scheduled departure time. A transit check is required between every two connected flights serviced by the same airplane. A daily check is executed when an aircraft stays overnight at an airport **(Yan et al, 2004).**

Light maintenance plan covers B737-800 A & L checks, B737-400, A320, A310, RJ aircraft's A checks and K&L checks of RJ aircrafts. The responsibility for all Istanbul A-check maintenance is Base. This means that all weekday A checks (except B737-400 odd numbered A checks, called as oiling check) are performed by Base Maintenance.

The A-check plan is a rolling ten-day plan reissued every three days. It is created semi-manually from TAMES data but only shows the aircraft by type, registration, remaining hour/cycle, check number and forecast date. This data is taken type by type. Forecast dates are far from reality, because of incorrect input aircraft utilization values, dates have to be recalculated.

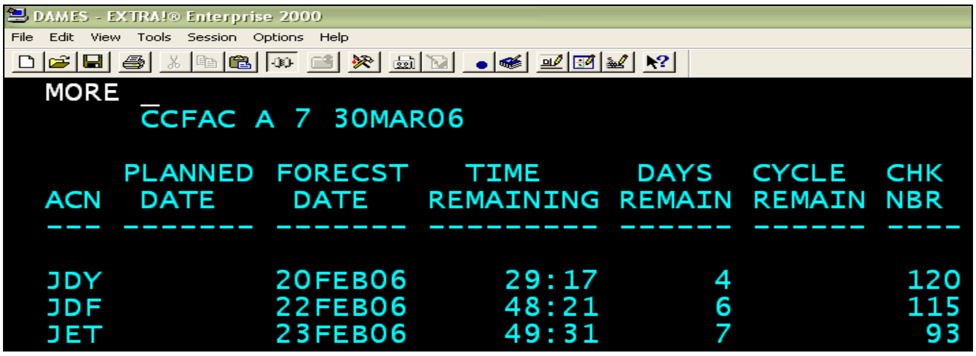


Figure 5.4: A snapshot of CCFAC transaction

In the process of line maintenance plans, remaining hours divided by daily aircraft utilization. Utilization depends on aircraft type and configuration. For example, remaining hour of JDY is 29h. It is divided by 9 hour/day. Obtained day value 3,2 placed on the third day on excel sheet as a small box. Every rows show an aircraft type. Calendar is produced manually and written on the columns. Check types and aircraft names are all written manually.

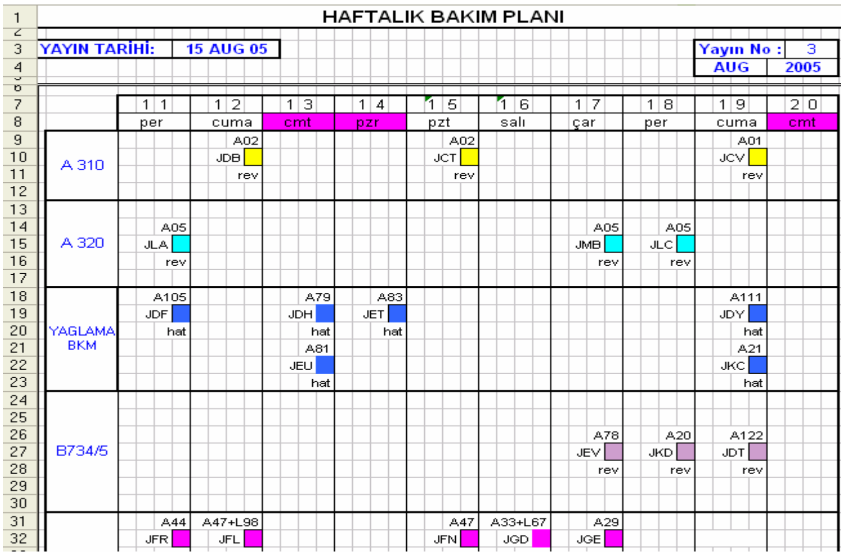


Figure 5.5: Line maintenance plan

5.1.4. Engine Plans

5.1.4.1. One-Year Plan

Engine Material Planning group within Production Planning and Control Department produces a Life Limited Parts ("LLP") expiry forecast and a forecast for lease engines based on lease return provisions. This is used as the basis for a one-year engine removal forecast produced by Production Planning. This plan only incorporates data on 'hard-life' requirements and specific 'on-watch' items such as AD limits; it takes no account of Mean Time Between Removal ("MTBR") or engine performance deterioration through loss of Exhaust Gas Temperature ("EGT") Margin unless the engine already has a negative EGT Margin. This therefore excludes many of the engine removals, which are actually required during the year because of 'soft-life' issues such as EGT Margin reduction. Currently, the one-year plan is used purely to provide Technical Supplies with a forward forecast for the procurement of LLP items all of which have both high cost and long lead times. The one-year plan is issued to EOs.

5.1.4.2. One-Month Plan

The Central Engineering Powerplant group reviews engine trend monitoring and reliability data from TAMES to maintain oversight of EGT Margin deterioration across all engines in the THY fleet. It provides a weekly update of EGT Margin status for all engines showing margin deterioration with a forecast of when the engine should be removed to Production Planning.

Production Planning combines the hard-life limits from the one-year plan and the soft-life data from Engineering to produce a one-month engine removal forecast. The one-month plan is issued to EOs Management and EOs Shop Planning and is incorporated into the one-month production plan.

5.1.5. Check Packages

5.1.5.1. Heavy Maintenance Base Check Packages

Check packages are produced by Production Planning using data from TAMES directly for the scheduled check content. Data for rotable component changes or Engineering Orders (EO) is also obtained from IT System but requires to be manually reviewed and added to the work package index.

Prior to issue of the work package index, Materials Planning is provided data on the planned rotable component and EO tasks and accomplishes a review of stock for each required item through IT System. This normally occurs 7 – 10 days before the input for Heavy Maintenance and 3 days before for A-checks and Line inputs. For material that is found to be 'nil-stock', then a material requirement is fed to Technical Supplies to try to obtain the parts and the data is also fed back to Production Planning to consider if deferral of the task can be considered as an alternative if parts cannot be obtained in time.

The target is to send work package index to Hangar Planning 10 days before the check input and this target is met.

The Work Package Index for each check due during the following week is provided to Base Maintenance and Hangar Planning for discussion on the Thursday of the week before the work is planned. The meeting attendance covers the following groups:

- Production Planning
- Aircraft Materials Planning
- Hangar Planning
- Base Maintenance Production
- Central Engineering
- Technical Supplies

Subsequent to the Weekly Meeting, Hangar Planning creates the following plan elements:

- Manpower plan by aircraft by trade and shift
- Aircraft by Hangar Bay
- Task cards for 'Hold Items' taken from the aircraft technical log and IT SYSTEM
- MS Project plans for major checks ('S' checks)
- Prints out the task cards and organizes for the control board to be loaded with cards by trade and zone.

The work package and plan is then handed over to the Production Supervisors who will often re-prioritise the manpower and effectively reorganise the plan provided to them. In parallel with this handover, the Hangar Materials Planner will commence the requisitioning of parts required to complete the check.

5.1.5.2. Third Party Check Packages

For third party maintenance inputs it is usual for the client to provide its own work package. The package is reviewed by Engineering prior to the maintenance contract being signed. The task cards for the agreed input may be provided much closer to the input date than the WPI for THY aircraft.

5.1.5.3. Light Maintenance 'A' Check Packages

Base Maintenance accomplishes A-checks at Istanbul and Line Maintenance accomplishes only A-checks planned at other line stations. Istanbul based A-checks are planned by Hangar Planning as for heavy maintenance checks. The line A-check plan is given to Line Planning ten days ahead and the work packages for these checks are provided to Line Planning 3 to 4 days prior to the planned input date.

Line Planning will plan the following:

- Staffing requirements
- Downtime – the inbound and outbound services for the aircraft
- Hold items

5.1.6. Material Planning Functions

Material is one of the key units within an airline's maintenance and engineering organization. It is the one that spends the most money (**Kinnison**, 2004). The Material Planning group is one section of the overall PP&C Department function. It is split into three groups Components, Engine and Aircraft. Its primary responsibility is to initially determine and maintain the stock holding levels for rotable components and economic order quantity (EOQ) for expendable parts.

5.1.6.1. Rotables Material Planning

The required spare quantity calculation process begins with initial provisioning and is maintained during the operation of the aircraft type. The planner calculates the required rotable spare quantity whenever there is a request from any shop or Engineering for a rotable after every scrap report is issued and checks with manufacturer recommended spare part quantity.

The planner manages the inventory level by regular review of a set of reports issued from IT SYSTEM :

- Nil stock list for 'No-Go' components (daily)
- MEL items (weekly)
- Nil stock list for 'Go-If' and 'Go' components (weekly)
- Deferred defect items (weekly)

5.1.6.2. Expendables Material Planning

The planner calculates the re-order point manually as per standard methods based on the usage quantity during the re-order lead-time plus safety stock by material planner. The planner checks the lead-time for the material from IT SYSTEM in order to estimate the usage during this period from historical data and adds a safety stock level, which is usually the estimated usage during the lead-time.

5.1.6.3. Component Overhaul Workshops

For the component overhaul workshops, shop engineers develop breakdown spare parts lists for each overhauled component part number when the component is added to the capability list. Material planners maintain the spare list and an oversight of stock availability based on the number of components passing through the overhaul cycle and the flying operation. They also manage component EO material requirements.

This task requires three material planners full time, one each for:

- Mechanical and Hydraulic shops
- Landing Gear, brakes, wheels and pneumatic shops
- All avionic (Electrical, Instrument and Radio) shops

5.1.6.4. Engine Materials Planning

Engine maintenance repairs engines, auxiliary power units (APUs), landing gear, and other miscellaneous parts from the hangar and component shops. Engine parts must compete with all these parts for equipment, personnel, and priority.

Engine removals occur for a variety of reasons. First, the engine has parts that are time restricted either by the manufacturer or the FAA. These parts must be removed, inspected, and repaired before their time expires. Second, the engine is boroscope inspected (a tube is inserted into the engine for viewing inner parts either by video or eye) on given intervals to determine wear. If the wear of particular parts is beyond limits, the engine is removed and overhauled to prevent a failure. Additionally, inspection of the engine occurs if performance is becoming deficient. The engines EGT margin may force removal of the engine. The goal is to remove the engine before a failure. The final reason for removal is an engine failure. This is a highly undesirable option. A failure may triple the cost of overhaul **(Gatland, 1997).**

The engine material planners cover the same tasks in terms of rotable and expendable parts as for the component material planners but for all Engine, APU and Fuel components. They produce a Life Limited Parts (LLP) expiry forecast and a forecast for lease engines based on lease return provisions to provide to Production Planning for the One-Year Engine Plan. In addition, they track scrap parts and components moving through the external repair cycle for return to meet engine or APU rebuild due dates.

5.1.6.5. Aircraft Material Planning

The aircraft material planners are primarily responsible for the monitoring and advising to Technical Supplies the materials requirements for:

- Aircraft Engineering Orders (EO)

- New or revised task cards
- Hold Items (deferred defects)

5.2. Engineering

Engineering is an integral part of the maintenance and engineering organization and their main function is to support maintenance. The engineering section is also responsible for developing the maintenance program at the airline, for providing analytical assistance to the maintenance organization, and for providing troubleshooting assistance to hangar, and shop maintenance personnel on difficult problems.

The engineering department provides preparation, study, and analysis of various aspects of the maintenance operation. They evaluate maintenance requirements and establish the maintenance program for the airline. They also evaluate suggested modifications of aircraft systems for possible incorporation into the fleet and provide technical assistance to maintenance **(Kinnison, 2004).**

Engineering have the key roles of

- Managing and publishing the required detail specification for the aircraft, the engines and the components and maintaining these configuration details through the life of the asset.
- Managing and publishing the authorized system of maintenance for the aircraft, engines and components.
- Managing and distributing all approved technical data in a form acceptable to the users.
- Providing support to production departments.

	K	RAMP CHECK	LINE CHECK (L)	A	B	C
B737-400				150 F/H		4000 F/H
B737-800		5 GÜN	250 F/H	500 F/H		6000 F/H
A310-200					400 F/H	15 AY
A310-300				400 F/H	450 F/H	18 AY
A319				3 AY		1 YIL
A320 A321				600 F/H		20 AY
A330				600 F/H		18 AY
A340				600 F/H		18 AY
RJ70 RJ100	70 CYC		100 CYC	500 CYC		1000 CYC VEYA 6 AY *
CESSNA 172				50 F/H	100 F/H	200 F/H

Figure 5.6: Maintenance interval matrix of THY

5.2.1. Summary of Functional Processes

This department is strong on schematics and process flow maps for the key functions that the department performs.

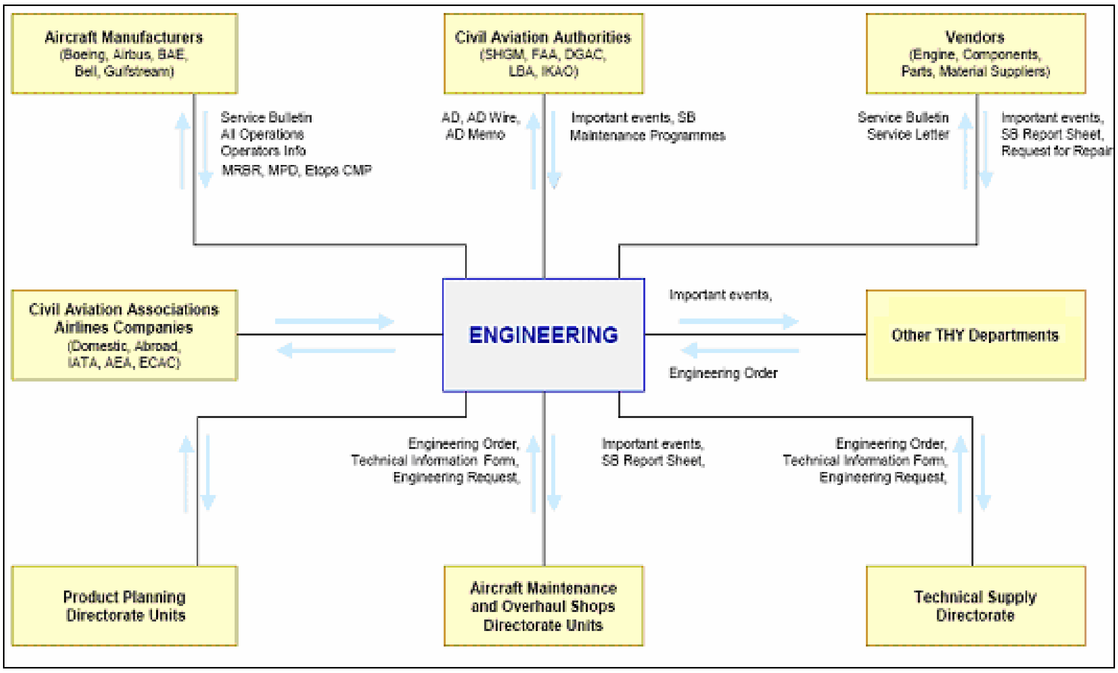


Figure 5.7: The interaction of Engineering and other departments

The embedded Technical Document Co-ordination centre is an example of a strong subset of Engineering and should be seen as *world class*. The assessment schematics are also very structured at a detail level. An overarching finding however would be that the schematics are all inwardly focused and do not position the Engineering processes into the wider context of the THY Technic processes.

5.2.2. Possible Problems in Engineering Departments

The problems in Engineering are largely areas where attitudes, interfaces, clarifications and lack of closure create unrecognized inefficiencies both internally and externally.

- Data Integrity: Engineering has the ultimate responsibility for the technical data.
- Engineering have to have strong interfaces with the rest of Airline leading to the charge of insularity.
- Engineering should have an induction training or mentoring template for new hires.
- Engineering should have strong interface with the Civil Aviation Authority.
- Engineering should have a process for Third Party work and thus the arrival of such demands cannot create disruption to the work flows within the department.
- Reliability as a process is a key functionality to be used as a tool for making improvements in the configuration and maintenance management.
- The role of support to production is very important.

5.2.3. Gaps in Current Departmental Performance

Measurement of a department such as Engineering is not an easy task because the workflows are in fact assessments of data, facts and options by a highly educated and capable workforce who unfortunately feel a little aloof or superior to the production departments where generally the people have a more practical bent. However measurement can be made, and standards can be set for tasks. This is achieved by measuring the tasks in terms of processing time and hands on assessment time, creating a database and then setting targets for the incoming work and monitoring completion. Engineering should be regarded as a *production* department in this regard.

- The product is approved data.

- The product has a time sensitivity
- The product has an economic impact and a cost of production
- The product is produced for the downstream departments in the production of MRO services.
- The product has a fit for purpose characteristic
- The product should achieve a certain aim or outcome.

These are then used as measurable parameters for individual and departmental performance.

Activity	Best Practice
AD assessment	I month*
SB assessment	3 months
OEM manual revision issue	1-2 weeks
MPD revision receipt to adoption	1-2 months**

Figure 5.8: Engineering performance measures

5.3. Aircraft Maintenance-Base

The Base Maintenance department in effect produces the primary end product of the MRO process. This product is the serviceable aircraft delivered back into service for the airline and also for the customer airlines. It is the major department that relies to a large extent on the performance of the other production and support departments of MRO process.

The three key support areas are Materials, Engineering and Production Planning and Control. Base Maintenance involves in depth scheduled checks, repairs and modification of mechanical and avionics systems are carried out in a hangar **(West of England Aerospace Forum, 2006).** The department occupies two large hangar complexes. The new hangar has many of the desirable features of a world class facility. It has a large open area and can contain a large number of aircraft of all shapes and sizes.

Base 1 has a total area of 51,000 m^2 and Base 2 has a total area of 80,000 m^2. Maintenance Bases 1 and 2 can provide maintenance services for 2 A340, 2 A310 plus 5 B737 or 1 B737 and 3 RJ types of aircraft simultaneously **(Turkish Airlines, 2006).** A curtained off area in Base 2 provides with a painting facility. The second hangar is older and still capable of holding aircraft up to the size of the A300. It currently houses very long term project aircraft which are laid up for long downtime such as the 146RJs which are returning, and several customer aircraft. This hangar has several variants of substantial aircraft docking and work stands which facilitate access to the aircraft.

A feature of the current operation is the value given to hangar flexibility. This sees aircraft remaining mobile during checks, and often being moved to enable other aircraft to come into the hangar.

The access, presentation and accuracy of data provided to Base; via IT SYSTEM -task cards in particular- can be a source of difficulty. This manifests itself as poor labour productivity as people try to assemble required data from a variety of sources. EOs and out of phase task cards are outside of IT System and have to be manually merged with the automatically generated pack.

There should be a cut off time for work to be loaded onto a Check and again this means that additional work shouldn't be loaded onto the Check in progress. The support departments should be careful about this. Materials should be obtained on time.

Another saying is that the longer an aircraft is in work, then the more man hours the visit will accumulate. The burn rates used for heavy maintenance are far too low and directly contribute to poor downtime performance. Finally the manner, in which the work is performed in the flexible mode the hangar uses, creates wastage as the aircraft can be moved during the check.

Typical industry best practice is to control the work package process, releasing it to production in time for production to plan to achieve it within the agreed target parameters. PPC collate and create the total work requirement including agreeing with the customer the basic Check parameters of downtime and resource cost, labour and material inputs. The pass off to Base should allow Base to accept theses target parameters and assume accountability for delivering to them. Any work that absolutely has to be added to the check is then negotiated onto the work package and due allowance for downtime and other issues made at the time. Equally in accepting the package the production department typically cannot defer or substitute work unless the support departments agree and change the compliances.

These burn rates when applied deliver *world class* turn times. Combined with a state of the art aircraft docking system and daily progress planning, tools which are used with effect to keep the labour *on the job* and provide them with immediate access to required services; and with the planning current; enables priorities to be adjusted without risking the completion target.

5.4. Aircraft Maintenance-Line

Line maintenance performs the work on the aircraft in service either directly or via contracted providers at out stations. Typically this operation faces pressures from the airlines directly for the on time performance of the fleet and the remedy of any defects on the aircraft. Overnight servicing, A Checks and completion of defect rectification is also a Line function.

Line maintenance operations are the frontline for an airlines aircraft maintenance organization (AMO). However they rely on the rest of the AMO for the timely deliver of a serviceable aircraft and the timely delivery of any other support services required. The primary role of Line maintenance is therefore to keep the aircraft flying in a safe and serviceable state; and to perform line servicing which essentially is a replenishment service for oils, water an tires etc.

Certain key processes are available to Line to continue the aircraft in service when defects require ground time or parts and material that is not available in the flight schedule. These include the use of the Minimum Equipment List (MEL); the deferral of repairs or component changes, and the use of loan or borrowed items from sources other than THY Technic. It falls upon Line to close out these issues as soon as possible and within any required criteria such as an MEL allowable use.

As a production department, Line Maintenance can reduce the impact defect rectification and scheduled checks have on the flight schedule through the use of effective planning. On a daily basis, Line Planning must ensure the effective deployment of required resources of staff, materials and ground time to meet the airline operation needs. Whilst much of this is routine, transit and turn around requirements, availability of material and qualified technicians, the appearance of a defect during the flying day can cause difficulty as it is largely unplanned and available planning time, unless advance notice is called in by the pilot prior to arrival at the station. The A checks can be planned with more certainty, however defects discovered during the check require similar planning reaction time to maintain the outbound flight assignment.

Provision of accurate and timely data to a Line operation is a prerequisite to good performance. Line also has the obligation to input accurate and timely data from their activities. Notwithstanding the above, it is a fact that Line will always assume a high-profile role within an organization due to its proximity to the flying operation and the pressures of time. As a result, AMO full support of Line Maintenance is essential.

The issues are the same as for the Base operation but in the time sensitive operation at Line, the accuracy of data, and lack of a centralized data source make can be a major source of distraction to management's focus on the day to day operations requirement for experienced decision making. Industry best practice provides update, user friendly IT support and data entry methods to Line operations.

Line achieves well A check periodicity at over 90% generally. 95% would be a good standard (see Table 5.1). THY good at all A checks except 737-400 and L checks of 737-800. The 737-400 needs some focus. This is because of short time interval, 150 F/H.

Table 5.1: Performance of maintenance interval utilization and performed number of maintenance

			A		L	
Fleet	**Year**	**Month**	**Yield**	**Number of Activities**	**Yield**	**Number of Activities**
738	2003		92%	207	87%	429
	2004		94%	209	89%	437
	2005		94%	206	91%	413
	2006	Jan.	90%	16	86%	34
		Feb	95%	15	91%	33
		Mar	95%	18	92%	38
734	2003		81%	289		
	2004		85%	321		
	2005		85%	331		
	2006	Jan.	86%	26		
		Feb	89%	19		
		Mar	87%	25		
310	2003					
	2004					
	2005		90%	31		
	2006	Jan.	93%	3		
		Feb	97%	5		
		Mar	81%	6		
320	2004		95%	13		
	2005		95%	73		
	2006	Jan.	95%	8		
		Feb	97%	5		
		Mar	96%	6		

Yield column is calculated through the formula 5.1.

$$Yield\% = \frac{Hours / Cycles\ used\ before\ maintenance}{Time\ Interval} \qquad (5.1)$$

6. RECOMMENDED FUNCTIONS AND PROCESSES

Many of the recommended function and process improvements are at least partially dependent on a substantial improvement in the IT support. This inevitably means that there is a requirement to accomplish extensive software upgrades to the current IT system or for the replacement of the current system with a new generation fully integrated system (e.g. an SAP type or similar) in order for these recommended improvements to be fully effective.

6.1. Production Planning and Control

All planning should be based on use of an integrated IT planning tool and all primary source data should be taken from the integrated IT system. All plans should be available electronically and real-time to all end users IT system needs to be upgraded to hold all required source data and the process of updating should be as close to real-time as is practical with single data entry of all data.

6.1.1. Long-Term Forward Capacity and Maintenance Plans

A five-year forward maintenance plan should be created. The current three-year heavy maintenance plan data can be used as a basis to start the process and develop it using input. This data will include fleet introduction and exit (lease return) plans. Include all aircraft heavy maintenance checks (C and above) using estimated expiry dates based on known operational usage, including landing gear changes (which are normally scheduled on 8 to 10 year lives) and estimated engine changes, based on known performance deterioration rates.

The plan should include gross estimates for manpower plus a nominal hangar bay plan and it should show estimates for third party maintenance inputs. This plan is primarily to highlight infrastructure problems, which may take in excess of one year to resolve and thus does not require to be agreed with production departments prior to issue. It will also highlight significant production peaks that exceed resource capacities.

This plan will be updated semiannually or more frequently when specific significant events become known which have an impact on the plan.

6.1.1.1. One-Year Plan

This plan should be created using an integrated IT planning tool such that it can be issued and reviewed in real-time by production departments electronically. It should be a rolling one-year plan formally updated two-monthly and a process of agreement between PPC and Production should be started such that the production units 'sign-off' and accept the plan.

One basic data source for the plan should be the technical production standards database containing the man-hour, downtime standards for each type of check for each aircraft type. PPC will be the custodian of the standards database; it will be the only section with authority to amend those standards and a structured and disciplined procedure will be required to manage changes which will have to be agreed and signed-off by all parties impacted by those standards. The intent will be to reduce the standards to world-class levels as the process and productivity improvements are achieved.

The plan will include the following data:

- Heavy maintenance check inputs, by type, registration.
- Planned input and output dates for each event
- All known third party maintenance events
- Full reference to check type/content and operator (for third party work)
- Staff by trade, by individual aircraft, showing actual requirement, planned total available and excess or shortfall in manpower.
- 'A' check inputs
- Aircraft check expiry hours/cycles/date.
- Special Inputs for major modification or other work which requires to be accomplished separately from scheduled maintenance inputs

- Major component changes – engines and landing gear. For engine changes data should be supplied by Powerplant Engineering to estimate the expected removal date for engine performance deterioration based on removal prior to reaching a negative EGT margin situation.
- Take account of average leave by month throughout the year especially high leave periods, average sick days by month, summer staff movement to Line plus known training impacts on available staff.
- Aircraft inputs by hangar bay.
- Visual chart of labour requirement against available to immediately highlight labour shortfalls.

6.1.1.2. Six-Week Plan

This plan will be a rolling six week period in future and will be extracted from the first six-weeks of the one-year plan so its value is primarily to provide additional detail and accuracy to the content of the one-year plan. It will be updated weekly.

The plan will include all elements contained in the one-year plan plus:

- Accurate staff leave/training updates from shops
- Updated and accurate input/output dates and times for all checks
- All A-Checks performed at Istanbul, requiring hangar bays
- Other Line special inputs planned and requiring hangar bays

6.1.1.3. A-Check Plan

The A-check plan is a rolling 30-day plan reissued every two days. It will be created by the integrated IT system and will show aircraft by type and registration. It can be accessed from anywhere.

The view like this:

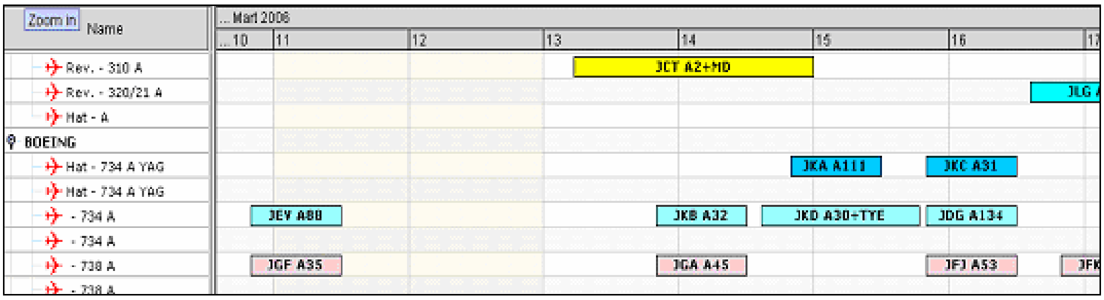


Figure 6.1: Maintenance plans are published through the intranet web site, the view of Line Maintenance

Most of the defined gaps have been passed over by implementation of the new scheduling program. This program developed by internal software developers. Line and heavy maintenance plans are available though a java applet for all users.

Man hour capacities and requirements are also calculated in this program. This makes easy to evaluate shops necessities. It is user friendly and visually nice.

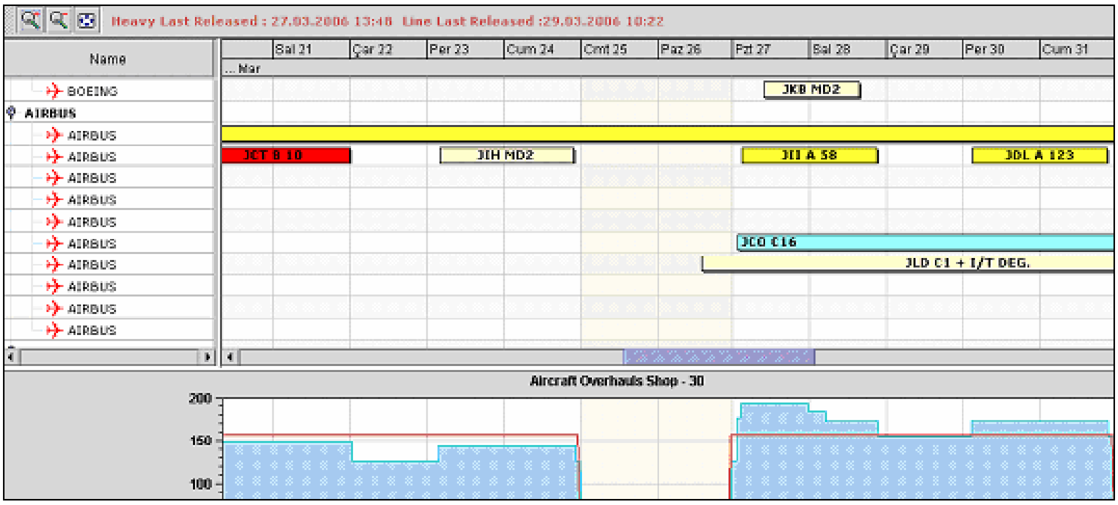


Figure 6.2: Maintenance plans are published through the intranet web site, the view of Heavy Maintenance

6.1.2. Check Packages

6.1.2.1. Base Check Packages

Check package content will be managed by Production Planning but created automatically by using data from the integrated IT system directly for all tasks; the scheduled check content, rotable component changes, Engineering Orders (EO) and any other tasks to complete the work package index ("WPI"). The WPI will commence with a summary page showing the resources planned in terms of:

- Labour man-hours split by trades
- Materials required by value
- Support shop or External services by value

The integrated IT system will require holding a standard Bill of Materials ("BOM") for each type of check for each aircraft type thus allowing Materials Management and Technical Supplies to effectively manage the materials requirements for future checks negating the need for manual stock checks by Materials Management for rotable component and EO tasks as currently. A specific BOM will be created automatically for each check for action by Technical Supplies to reserve all required parts for the check creating a 'kit' or 'pre-load', which will be delivered as a kit of parts to the production areas prior to aircraft input.

For all heavy maintenance inputs a provisional WPI will be created and issued to Base Maintenance for initial review. A provisional BOM will be created and issued to Technical Supplies for initial kitting of parts. These will be issued at a set point prior to input date dependent on check type as follows:

- S check 12 weeks
- Heavy C check (C4 etc) 6 weeks
- C check 3 weeks

Parts kitted for a specific check can still be used to overcome an AOG situation but this will require an Immediate Operational Requirement ("IOR") parts procurement process to be initiated to obtain a replacement part prior to aircraft input. Once kitted for a check parts will not be used for any non-AOG event.

For any BOM item that is found to be 'nil-stock' then Technical Supplies will work to obtain the parts but will also feedback the data to Production Planning to consider if deferral of the task can be considered as an alternative if parts cannot be obtained in time. Using the provisional BOM should minimize the number of events where parts cannot be obtained in due time.

In addition a cut-off date will be set for the final WPI and BOM after which nothing except new mandatory items will be added. This will be set at:

- S check 4 weeks
- Heavy C check (C4 etc) 2 weeks
- C check 1 week

At the cut-off dates the final WPI and BOM will be issued to Hangar Production Planning and the final BOM to Technical Supplies.

A specific Check Input Meeting (CIM) will be called by Production Planning to discuss the content on an individual WPI for S-checks and heavy C-checks. The WPI for each C-check and other inputs due during the following week will be provided to Base Maintenance and Hangar Production Planning for discussion at the Production Meeting (PM) on the Thursday of the week before the work is planned. The meeting attendance at both the CIM and regular PM will cover the following groups:

- Production Planning
- Aircraft Materials Planning
- Hangar Production Planning
- Base Maintenance Production
- Central Engineering
- Technical Supplies

The conclusion of each meeting will be the sign-off of the total package by all involved sections and this then becomes an agreed target for each section to work to achieve.

Subsequent to the CIM or PM, Hangar Production Planning creates the following plan elements:

- Manpower plan by aircraft by trade and shift
- Aircraft by Hangar Bay
- Task cards for ‘Hold Items’ taken from the aircraft technical log and IT SYSTEM
- MS Project plans for major checks (C4 and ‘S’ checks)

- Prints out the task cards and organizes for the control board to be loaded with cards by trade and zone.

The package is then handed over to the Production Supervisors for action. No changes will be made to the Hangar Plan as issued other than by agreement of Hangar Production Planning and the Base Maintenance Manager.

6.1.2.2. Light Maintenance 'A' Checks

The A-check plan is issued to Hangar Production Planning and Line Production Planning ten days ahead. A WPI and BOM will be issued to Hangar Production Planning and Line Production Planning for all A-checks five days prior to the planned input date. The BOM will also be issued to Technical Supplies.

Hangar or Line Production Planning will plan the following:

- Staffing requirements
- Downtime – the inbound and outbound services for the aircraft
- Hold items
- Hangar Plan (Istanbul checks only)

6.2. Engineering

As noted in Chapter 5, Engineering has a product focus. Equally the key roles performed by this department are practiced well internally. Thus many of these recommendations are in the nature of improvements and added checks and balances rather than significant process changes.

6.2.1. Recommendations on Processes

An immediate improvement is required in the data integrity. This should be addressed by a cross functional team lead by Engineering and tasked with identifying all sources of data corruption or omission and developing procedures and disciplines within the respective areas to correct the ongoing situation.

Existing data should be cleansed by another group of people. This action is a pre requisite for the implementation of any new ERP process. The outcome of these first two initiatives will remove the present frustrations that this situation creates and immediately reduce the amount of resource that is spent modifying reports and outputs to try to move nearer to the true state. Internal performance targets should be set and agreed upon for the routine business activity of the department and efforts made to plan work flows and introduce performance measurement. The concept of focusing the department on its own products, and the iterative improvements from feedback and also key roles such as reliability will be developed. Engineering should meet with the other departments and agree where coordination and cooperation touch points exist which if activated will improve the overall business performance.

Some roles will be moved into more appropriate departments such as Vendor warranty and some roles will move into the department such as shop engineering, functionality we will call "Engineering Cells". An induction training program and career path should be developed for both new and existing staffs in order to broaden their knowledge and experience. For new staff a mentoring regime should be introduced to accelerate the rate at which they become fully effective.

6.2.2. Key Changes

Given that this department begins to interact and coordinate better with the other functional areas then the required outcomes will become evident. This outcome will be dependent upon the leadership and the adoption of management styles and practices.

The shop engineering function is to be made part of Engineering with the shop function being renamed as Engineering Cells. These people would be on the budget of the shop from a numeric perspective and daily administration, but would report for their function to Engineering. This means that these staffs can be rotated through engineering and the shop role be used to get the Engineering people closer to the activity of the shop.

The key functions of the Cells are

- To provide interpretation of the already published and approved technical data.
- To be close to the work in progress and to improve their own knowledge and understanding in a practical workshop.
- To obtain new approved data where there is a production need.
- The reliability function needs to be refocused to extract the maximum benefit from the process.

Engineering will eventually specify and populate the recordable structure of the aircraft for part numbers and maintenance periodicity under an ERP regime. They must also carry the responsibility for the specification of data entry requirements as the organization processes serial number data and work packages. Leadership for the whole question of data, the need for it and the need for accuracy should be demonstrated by engineering. ERP system design will by the very nature of the disciplines contained in the functionality software force compliance with the mandatory fields but the soft fields, such as reason for removal, need to be completed at the workface and by people who are currently not doing this.

The whole question of addressing timely co-ordination and interaction with the other departments as engineering process the assessments for changes has been addressed by improving the internal schematics. However this remains an important change and one which the engineering leaders must support and practice. In particular engineering, like other departments also, must respect and observe where the key functionalities reside and who is best placed to provide the required accurate data.

Vendor relationships will become the domain of the Materials Management group so as an example; Engineering would concentrate on their vendor communications and discussions on the technical aspects and leave the financial negotiations to the procurement or vendor management staff. The style of contracting with vendors will also be changing to give effect to volume discounts and other overarching issues and engineering staff on the face may not be fully aware of those issues and developments.

Feedback systems need to be strongly reinforced and in some cases introduced. Engineering leadership, under the proposed performance management systems, will have an interest in the receipt of feedback as a continuous improvement process for the department. They will need to be proactive in seeking feedback on their department's products, performance and perception by their customers. This will be done by the simple introduction of a feedback sheet with every EO which can be used by the user department to record and feedback issues, problems, errors and interpretative matters. The aim is clearly to improve product quality and avoid wastage in the future.

When engineering make or sponsor a decision to embody a change or to achieve a desired end result, they need to demonstrate that they are interested in how that decision achieves the original intent or purpose. An induction and training template will be developed so that newly hired staff can quickly be absorbed into the organization and be made productive in the shortest time possible. The training will include a mentoring segment whereby the young incomer works with and benefits from the opportunity for close interaction with some of the senior people.

Customer work, will as far as possible flow through the same business processes. An effort will be made to help engineering staff understand the value and benefit of third party work.

The functionality of providing support to production will be improved by the absorption of the shop engineering function. It will be further enhanced by the engineering leadership working with the shops and production areas to agree and put in place any coverage for any present shortfalls. The solution will lie in some rosters for the engineering cells, supported from time to time by personnel from engineering.

6.2.3. Expected Benefits

These will be seen as

- A strong contribution to developing the team culture within MRO.
- A more focused department and organization which will achieve an improvement in throughput and processing time due to a clarification of role.
- An improved customer perception of the department with the increased coordination and cooperation.
- An improved quality of the data and data disciplines which will deliver productivity improvements across the organization as the data becomes to be trusted.
- An improved quality of engineered changes as the department responds to feedback and embeds process improvement into their daily work habits.
- A new sense of purpose for the people in Engineering as they grasp the roles and a sense of career structure and team playing.
- An improved process which sees proposed changes overseen and the actual benefits achieved compared with those anticipated in the assessment stage. This will lead to further improvements and understandings which will flow into other assessments.

6.3. Aircraft Maintenance-Base

Base is the largest employer of MRO and delivers the ultimate MRO product back into service. It is a key functionality and is where the combined delivery of all the other functions within MRO counts. As the largest labour user the key for success is the deployment of that labour at the highest levels of productivity.

6.3.1. Recommendations on Processes

The thrust of the proposed changes is aimed at improving the quality of support provided to Base from the other areas of MRO. This means the delivery of timely and accurate data so that Base management can plan the activity to achieve the targets. If flow is obtained, major checks can be performed without disturbance.

6.3.2. Key Changes

The work package is to be delivered to Base in sufficient time for Base to be able to produce a project plan for each aircraft induction.

- 4 weeks ahead of input for a C Check
- 6 weeks ahead of input for a 7C or 6year/12year Check

Each work package is to have a summary which will contain the key resource elements and sizing and this summary will be the pass off from PPC to Base and become the agreed target for the C Check. Base supervision in signing off for this summary will be held accountable for the delivery of the project within 10% of this target.

The summary should as a minimum contain

- Total man-hours by trade and at current MRO standards, and in category for planned work, structural cards, corrosion cards and a work arising allowance
- List of all component changes and tally sheet; this to include any items forecast to expire before the next check where those items are not ideal for a change in a Line environment.
- An allowance for deferrals from Line
- List of all modifications (EOs) to be performed
- Input date and time

- Output date and time

Once issued the work package is to be achieved in full by the Base management and they have no ability to defer or postpone work called up in the work package. If a situation becomes unavoidable then they must refer to PPC who will coordinate to see if a deferral can be allowed and to replan as necessary.

Once issued nothing can be added to the work package by any other part of MRO unless PPC achieves a coordinated agreement that a task must be added, and the Base management agree and any change to the planned targets are agreed. All work packages issued will have fully available engineering task cards and other instructions and all required (planned) materials will be to hand and allocated to the check.

Base planning will then take the work package and produce a detailed plan which will have as a minimum the following features

- A zone/area breakdown of tasks
- A basic services availability, such as jacking, power, electrics etc
- Access and inspections to be tasked first
- A critical path
- Labour team and shift allocations.

This plan will be updated on a daily basis with the planner assigned to the check and working closely with the project leader (Foreman). Each day there will be an assessment made of the delivery date and resources will be added to the check if required, overtime or extra staff, to maintain the plan. Should a delay become inevitable then Base will justify the change to PPC and a new target agreed. PPC will coordinate with the airline customer. Customer aircraft work packages will be subject to the same discipline.

A better coordination and interface with Line maintenance will be sought by Base management to ensure that required work on the Check as a result of Line is achieved. Base will also be sensitive to the Line operation and will attempt to deliver a clean aircraft, no carry over or deferral items, to Line.

Base management will seek to achieve *world class* burn rates for each Check. Once a resource is allocated to a project plan, then that resource will be maintained and the project leader held accountable for the delivery to plan. As an adjunct to this, a study will be undertaken to see how the workforce can be held on the task for as much of the downtime as possible. This will look at fixed docking which will contain all the necessary tools and data to allow the workers to stay working the aircraft rather than leaving the task to go and find the tools or data. In the interim the present practice of moving an aircraft on heavy check will be discontinued.

6.4. Aircraft Maintenance – Line

As the front line in keeping the aircraft serviceable, Line has a natural demand for accurate data and user friendly data systems. Performance metrics are not readily available and these allow area management to demonstrate achieved results and serve to help the Line staff better understand what is expected of them.

6.4.1. Recommendations on Processes

Line needs to focus on current data sources and flows and design work amendments, which minimize the effects of the problems. Where Line staff performs work on aircraft or aircraft components without proper completion of the paperwork there is a need for disciplinary action to be taken. Where Line is the recipient or the deliverer of a service to another MRO department then better communication and understanding of each others needs are required.

6.4.2. Key Changes

The Line planning function needs to be strengthened so that there is as much data available as possible to enable resources to be planned to the tasks. Where data does not exist on task cards then Line should require the data to be made available from agreed standards.

It should be clear that what tasks are routinely planned into the Line operation. The advisability of loading EOs should be considered into Line under any circumstance. All efforts should be made to regularize the Line work rather than see things loaded there that create disruptions or unusual requirements. Line needs access to current and accurate data.

All data entry should be in IT system or advised to the next destination airport Line operations (or contractor) before the aircraft arrives. Line and Hangar planning need to cooperate more on the exchange of data pertaining to inbound heavy checks. This will enable the Base project planner to pre plan the work before the aircraft inducts.

Where Line needs access to a hangar for special cases, then it should cooperate with Base accordingly. Line should not be loaded any work that requires facilities or equipment more usually associated with a Base operation. Should planned work of that nature be required then PPC should consider a special day off for maintenance rather than adding inappropriate work to Line.

7. AN APPLICATION OF LEAN THINKING IN AIRCRAFT MAINTENANCE PLANNING

After understanding whole Aircraft Maintenance System, the line maintenance planning process is chosen for lean application. For this reason all literature searched for articles. There a few articles written in lean thinking and aircraft maintenance planning process. Combining lean techniques and mental process is the difficult part of this project. Throughout this part, principles of lean thinking have been applied to many aspects of the line maintenance planning process.

First of all, repetitive and non value added operations were defined in detail and then the system analysis has been done. Capacity limitations have been described carefully and daily aircraft utilizations (See Appendix A) were defined by commonly used statistical methods. Finally, on value stream map good improvements had been obtained.

Application of lean thinking covers the lean technique proposed by Womack.

- ✓ Specify value
- ✓ Define Value Stream map
- ✓ Flow
- ✓ Pull
- ✓ Perfection

7.1. System Analysis of the Planning Process

Process mapping, which may be thought of as a subset of value stream mapping, visually displays precisely how a particular process is carried out. The map reflects what actually happens rather than what you believe should happen so that opportunities for improvement can be uncovered and standardized processes developed **(Kullmann, 2004).**

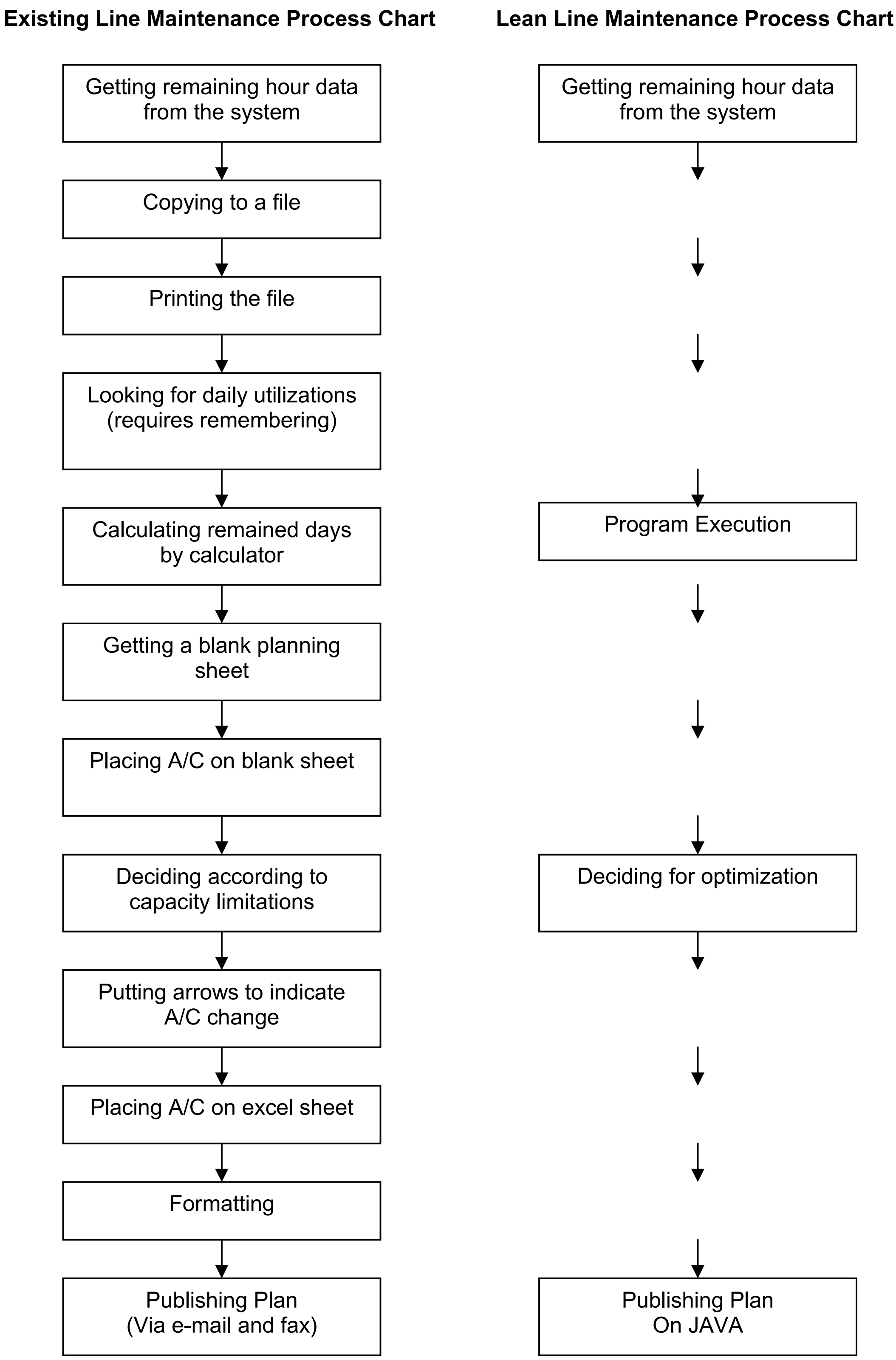


Figure 7.1: Comparison of existing and lean line maintenance process

In order to grasp the philosophy behind the methods of capacity usage, we must first understand the activities taking place within the value stream and time consumed performing them. Hence, it is urgent to draw maintenance planning process within relational departments. A cross functional process chart is suitable to see the flow of information and material. This chart is presented at Appendix B.

As it can be seen from the cross functional process chart planning process is sophisticated and involves many people. Commercial departments, system, engineering, production planning & control, base and line maintenance have significant roles in planning process. For development and detailed analysis on lean thinking Line Maintenance Planning is chosen. Line maintenance planning is important because of its dynamic environment and reflections on daily operation.

Current process is analyzed step by step. Starting with the process map is the easiest way of looking from the above. Figure 7.1 shows the existing process and suggested model. The second process map is produced after lean thinking studying.

7.2. Specifying Value

Making a system lean requires answering many questions and specifically for this project which are:

- Exactly what we need?
- How can I improve the quality of my work?
- How can I reduce the cost of the products I work on?
- How can I improve cycle time or delivery to my customer?
- What is waste in this process?

After answering these questions, it is time to define value and waste. Line maintenance planning process should be translated into Value Adding (VA), Non Value Adding (NVA) and Necessary but Non Value Adding (NNVA) recommended by Yasuhiro Monden (1993).

7.2.1. Value Adding (VA)

This step is equal to specifying value. The question is exactly what we need? Publishing line maintenance plans in time without any mistake is the value of this process. Therefore, what we exactly need is placing aircraft on timeline in such a way that the maintenance intervals are used up to the limits. This is exactly what the customer want in the end. The customers of this process are operators of the maintenance which are line or base maintenance, maintenance package prepares in PPC department and other flight scheduling departments. All these customers just want to know that which aircraft is going to be on the ground and when.

7.2.2. Non Value Adding (NVA)

There are some activities which clearly create no value (and adds cost), which can be removed immediately from the planning process **(Francis, 2005).** Printing out time remaining of letter checks and also printing blank planning sheet for placing aircrafts create unnecessary paperwork. This paperwork completely can be removed from the system. Also the step of placing A/C maintenance day on blank sheet is a non value added activity because it is a buffer process before placing A/C on excel sheet. It is repetition of placing.

7.2.3. Necessary but Non Value Adding (NNVA)

The activities which create no value but are unavoidable can be eliminated by the current operating constraints of the technology are defined below. These are the Kaizen bursts which can be seen on Current State Value Map (Appendix C).

- Calculating the amount of days left to the maintenance activity is primitive and far from professional. Manual calculation is open to mistakes and very vulnerable. This step also requires remembering daily utilization of A/C. There are nearly 100 aircraft and their utilization is changed seasonally. Moreover some aircraft has same fleet name but their seat configuration is different. Therefore there is diversity for utilizations in the same fleet.
- Writing ACN'(Aircraft Name)s and checks numbers open to failure that is because of they can be written wrongly, due dates of maintenances could be over. This generally cause check number and ACN mistakes. This should be prevented for obeying aviation rules and authorities.
- Drawing, dying, and also formatting lines which are ruined in character or quality are waste of time but have to be done. After placing on excel sheet from the paper, they have to be formatted for visualization. Beside this, if there is a need

of changing A/C, the cell borders will be ruined. They have to be formatted once more. Some checks have to be shown in different format (For example, multiples of10th checks of B737-800 A/C must be longer than others). There is a need of recognizing these differences.

- Creating calendar day by day and trying to differentiate weekends, putting numbers for following maintenance day are time consuming activities. After calculating maintenance day, there is need of counting and numbering the days. This is also a source of mistakes which should be prevented.
- Publishing way should be differentiated. Sending e-mail has sort of difficulties and weakness. Publishing via a-mail increases system requirements. If the user mail storage is not enough, they possibly cannot reach the maintenance plan. This situation cause repetitive mail sending. It is possible to build a new environment to publish to make users access the most update maintenance plan. For this reason new software developed on JAVA. It's implementation caused more waste. After placing aircraft in timeline they have to be drawn in the Java software to publish other departments. This means that every aircraft's name, check type and check number with suitable time requirement is written on Java boxes, every two days for nearly 100 maintenance activities. This newness needs some improvement to make the system lean.

7.3. Value Stream Map

According to process map Current State Value Stream Map is defined and presented at Appendix C. Value Stream Map tools are used in drawing step. The pace after pace time required by the transaction is measured. There are Kaizen bursts to show the areas that are open to improvement. These areas also show the non-value added parts of planning process.

Any movement of people or equipment that does not contribute value to the product is waste of motion. Walking to get files, documents, supplies, and make copies is also waste of motion **(Kullmann, 2004).** There are two unnecessary walking which can be eliminated. First one is walking for printing which is equal to 6m/planning. The second one is walking for fax machine to transmit printed line maintenance plan sheet to the other departments that cannot have an e-mail access. There is no fax machine in planning department. Generally fax operation is interrupted the flow of planning process because machine frequently have breakdowns. This takes 50m and nearly 15min to accomplish fax operation. After fax machine, it needs to be approved if it is transmitted to the target departments.

⇒ The run time of current line maintenance is 283 min and the time spent for set up is 88 min. Total duration of line maintenance plan is 371min which is equal to 4h 11min.

In order to remove all waste and improve process efficiency software developed. As a practical and sufficient tool for a limited budget, we have found it appropriate to use a Microsoft Excel spreadsheet that is fed by a source code written in Visual Basic. Software development removed many steps and accelerated planning duration. After realizing suggested kaizen bursts, the planning duration is shortened incredibly. Future state value stream map is presented in Figure 7.2.

⇒ The run time of future line maintenance is 38 min and the spent for set up is 19 min. Total duration of lean line maintenance plan is 57 min.

The cycle time improvement is 85%. This is a good result to get. This means that every day 3h is saved not wasted.

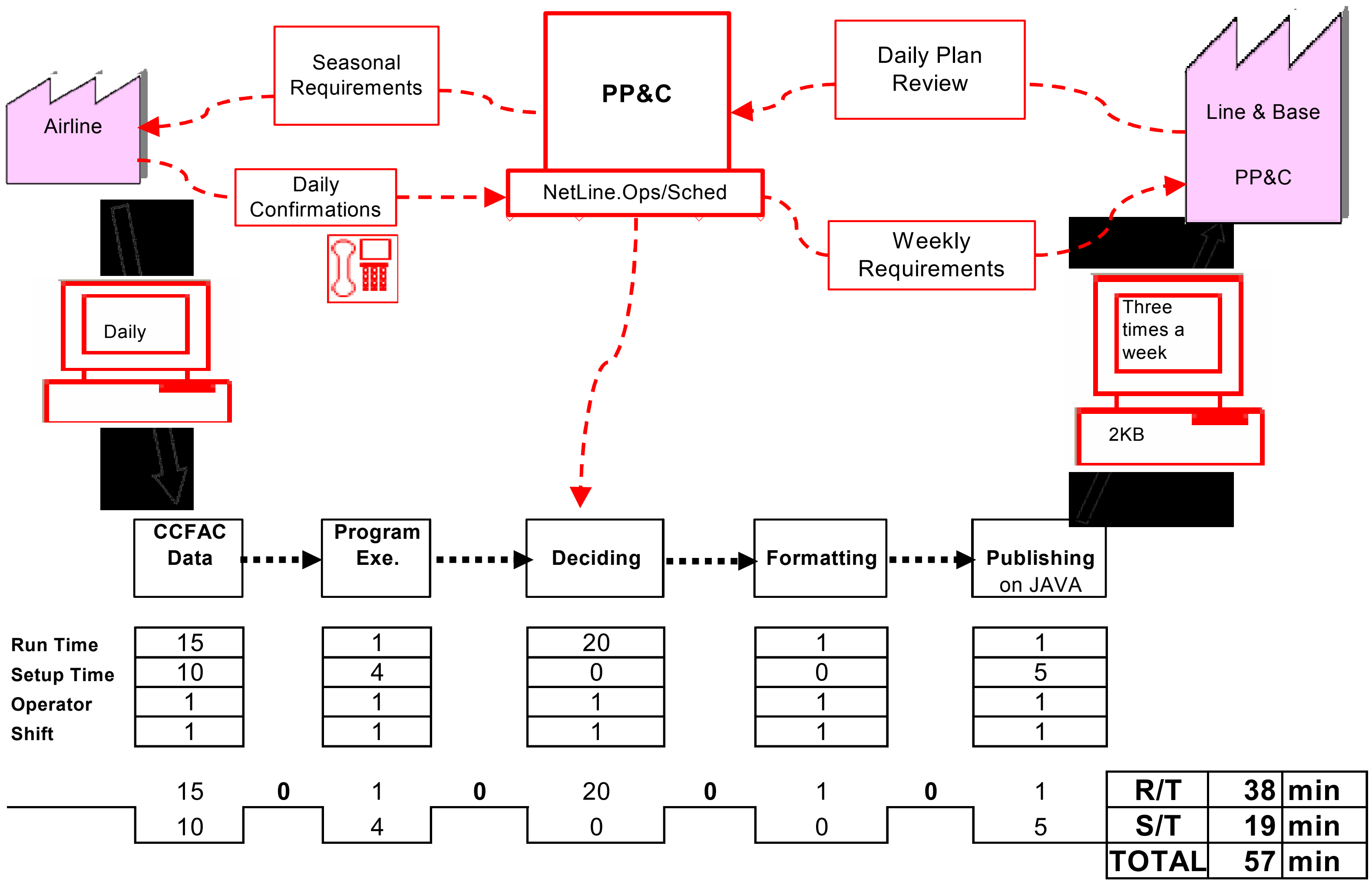


Figure 7.2: Future State Value Stream Map

7.4. Deficiencies of existing system

Existing system can be shortened through the improvements in Kaizen bursts. On the other hand, lean thinking proposes perfection. These requirements should be supported by removing deficiencies.

Planning horizon is 10 days and not enough for other shops to do man*hour planning, scheduling maintenance packages and evaluating task cards so, line maintenance plan should be known before 15 days. If any check is delayed, that is going to interfere with all the checks that are happening in planning horizon, so you need to reorganize all your planning in the medium to long term **(Aircraft Technology Engineering & Maintenance - December 2001/January 2002).** In this perspective, 30 days will satisfy all these needs.

7.5. Capacity Limitations

Before starting improving the system all the limitations should be defined and made clear. When line planning operation observed, four limitations needs pay attention in the current system. These limitations can be used a source for further operations research study.

Hangar space limitation:

Only 2 main A check can be performed during a night in Istanbul. On the other hand, it is possible to perform 3 A checks under indispensable conditions.

Outside Station Limitation:

There are 3 outside stations to perform line checks: Antalya, Izmir and Ankara so, maximum of 3 checks can be performed in a night. Sometimes it is not possible to arrange all the maintenance aircrafts assign to an outside station because daily flight route. When this limitation considered, two line checks in a night become preferable.

Man*Hour capacity limitation:

Base maintenance does not work at the weekends. For that reason, line maintenance can only perform one A check in Istanbul.

Type limitation:

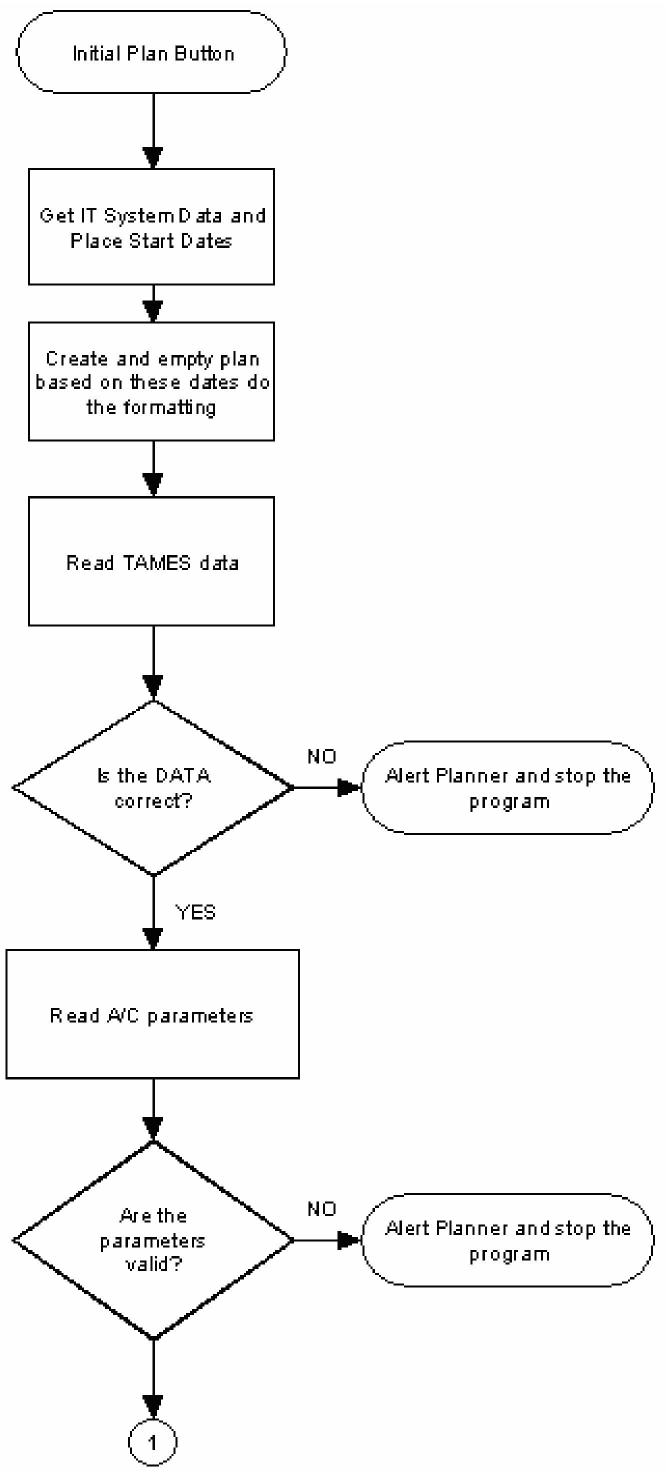
Line maintenance can only perform Boeing aircraft's maintenance operation during weekends.

7.6. Software Development

Ideally we would eliminate most of the operational transactions in the above processes because they are wasteful in themselves and they cause more waste. After system analysis, defining all the requirements, a comprehensive excel macro is written in Visual Basic. The algorithm of the software is presented in Figure 7.3. The scheduling software has been developed in 8 months and took the place of manual planning which had been used in PPC Department since the beginning. First of all, initial tests are done, then old and new program run in parallel. Same solutions did get from the manual operation and newly developed software. The results are robust and satisfying. At last, old planning process has been abandoned.

The software is based upon five sheets:

Parameters Sheet: A parameter sheet (see Figure 7.4) has been prepared to give enough flexibility to the users such as color, placing and daily flight hour. Every fleet type has a unique color for each letter check and these colors can be changed by the user. Moreover, two options are added to the parameter sheet. The former one enables user to decide where to place aircraft. It is possible to place aircrafts one day before regulated by FAA, because of dynamic characteristic of the Line maintenance. Unscheduled failures effect man*hour calculations of line maintenance, so a letter check of an aircraft may put off to the next day. The latter one enables user to place an overcapacity aircraft to the next day or the previous day. These overflow aircrafts are colored in red so easily differentiated from the others. In final, all the aircrafts daily utilizations are changeable by the planner according to seasonal flight variations. The last column of the Figure 7.4 shows each aircrafts flight hour cell.


Initial Plan Button
Get IT System Data and Place Start Dates
Create and empty plan based on these dates do the formatting
Read TAMES data
Is the DATA correct?
NO
Alert Planner and stop the program
YES
Read A/C parameters
Are the parameters valid?
NO
Alert Planner and stop the program
1

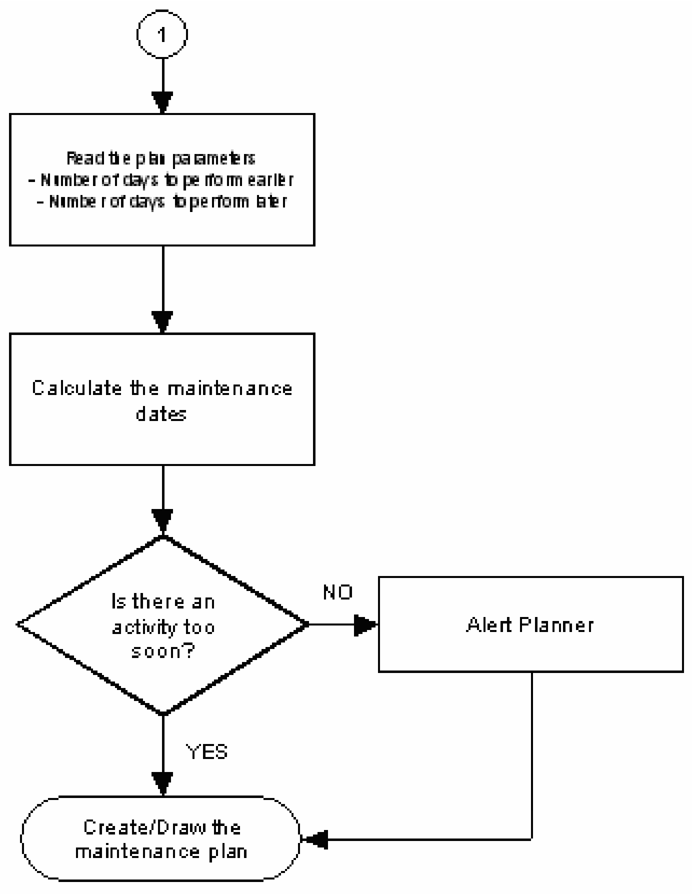


Figure 7.2 : The algorithm of the planning software

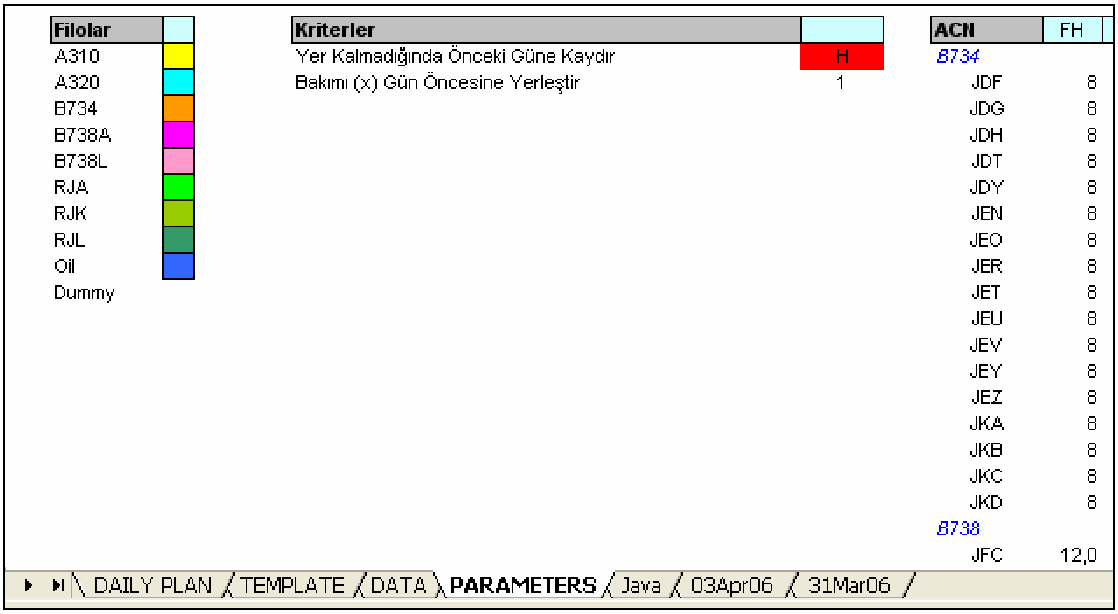


Figure 7.3: Parameters sheet

Data Sheet: Data sheet consist of TAMES-CCFAC transaction information. Txt formatted data is changed to xls format here. Fleet and check type data is got from this sheet. For the present, there is no connection with TAMES and this program, this process done manually. In the future, it is possible to connect them and get the information automatically. There was an original view of TAMES data in the fifth chapter and data sheet view is below (see Figure 7.5).

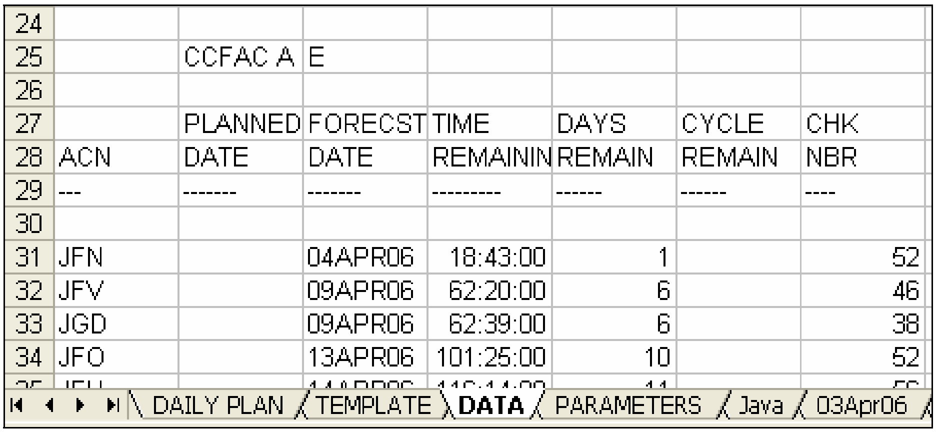


Figure 7.4: Data Sheet

Daily Plan Sheet: This is the main planning sheet (see Figure 7.6) and revised 8 times during development phase. At first, in transition phase, plans were published the same as before, covering 10 days. By the time, after implementation of new publishing tool over intranet, 10 days-plan was quitted. In stead of this, 30 day was selected for planning horizon.

CCFAC date is written in this sheet and according to this date all calculations are done and accepted as 1. Weekends and calendar dates are produced and dyed automatically. Thus, the possibility of calendar mistakes is removed from the planning process. In the beginning this process was done everyday by writing and erasing. Line and base maintenance information are added according to check number and calendar date. In the last release of this program a counter is joined to the program. This makes easy to see shops capacity and gives general information about the number of planned maintenance activity.

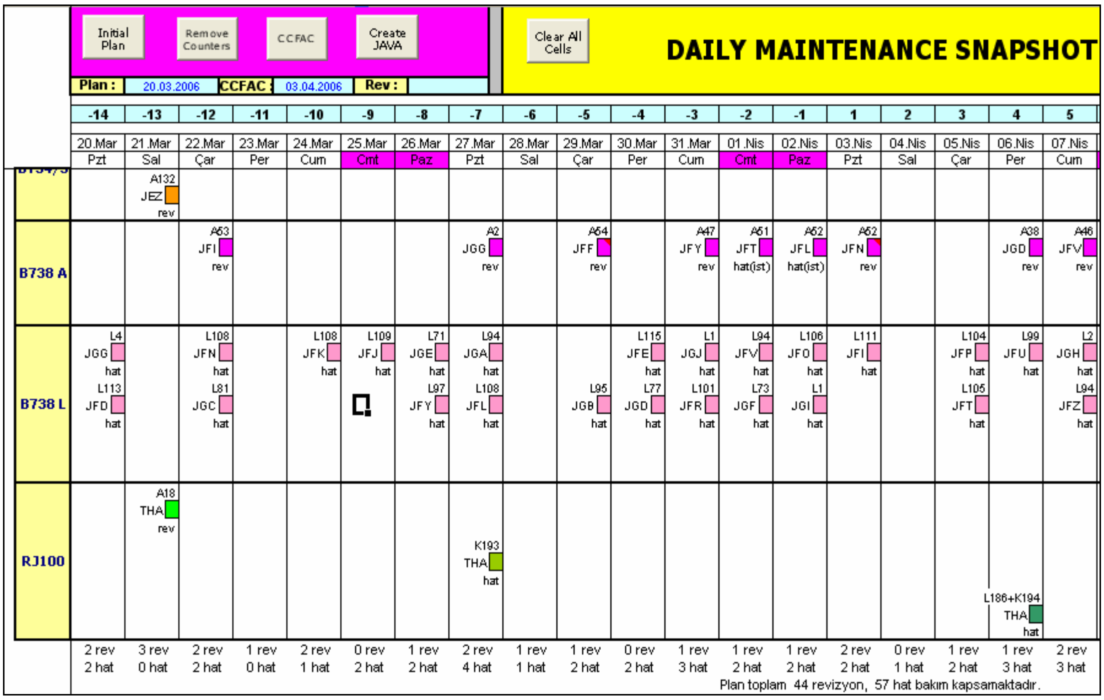


Figure 7.5: Daily plan sheet

When CCFAC button pressed (see Figure 7.7 and Figure 7.8), available dates of checks can be seen on the same sheet with the published plan. This is the most time saving property of the program. Below, there is a snapshot of this process.

When CCFAC button pressed once more, the entire format is edited and disorders are removed from the sheet.

1	2	3	4	5	6	7	8	9
3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr
Pzt	Sal	Çar	Per	Cum	Cmt	Paz	Pzt	Sal
A6 A6 LI JLI 2|16 R				A1 JPA R	A1 PA 7,1|50			A3 A3 MF JMF 10,9|87 R
A135 JDG H	A31 A31 KD JKD 3,5|28 H	A33 KB 4,8|38	A95 A33 ET JKB 5,5|44 H	A95 JET H			A89 A89 EY JEY 9,4|75 H	A133A133 EZ JEZ 10,1|81 H A129 EN 10,9|87

Figure 7.6: Daily Sheet in operation

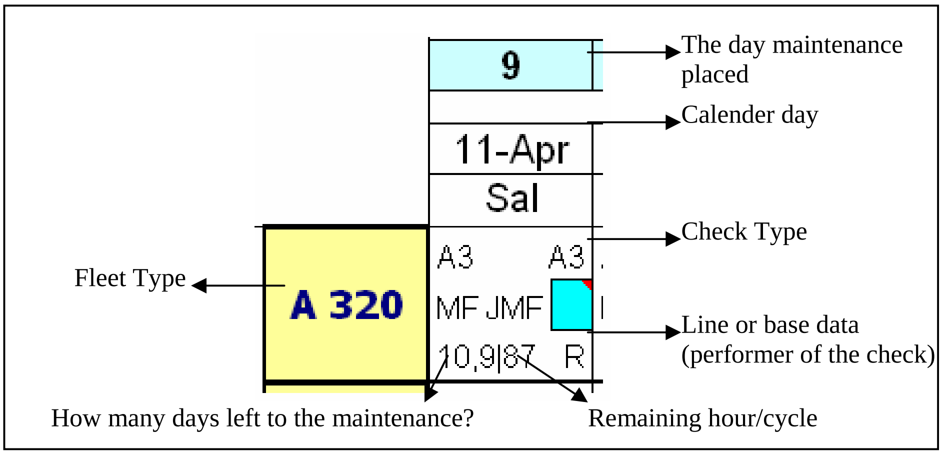


Figure 7.7: Zooming to daily sheet in operation

Java Sheet: Java sheet (see Figure 7.9) has been added after implementation of Java program. Until this time maintenance plans were distributed via e-mails in excel sheet format. Then by the implementation of the new distribution program, all users made available to access maintenance program. This program caused a requirement of converting excel data to Java data and so new codes added to excel. Thus, all Java boxes created from excel with one button pressing.

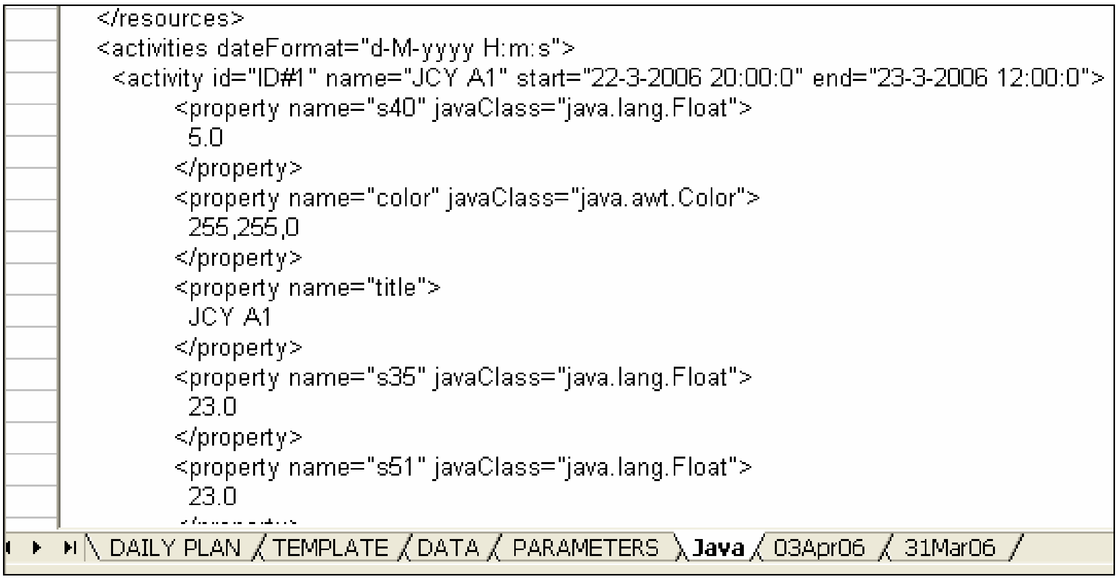


Figure 7.8: Java Sheet

7.7. Benefits of the Lean Planning Process

Jones (2004) states that, "The real opportunity from going lean is to be able to do considerably more work with the same resources at almost no additional cost". This opportunity achieved through the new tool. Planning process has significantly shortened after implementing new software. Previously, planning and publishing maintenance plan took nearly 4,5 hours and now it only takes 1hours. There is a 85% improvement in planning duration. Everyday nearly 3 hours freed up making 15 hours in a week. Wasted three hours becomes valuable time of a planning engineer creating enough time for research & development.

Old planning process was requiring paperwork, pencil, calculator and many arrows to indicate check changes. CCFAC data had to be printed out for calculating and placed aircraft had to be marked by pencil. Maintenance boxes had been drawn to a blank planning paper then to the excel sheet. All these works were eliminated accordingly; paperwork has been reduced by 95%.

The need of following calendar, reorganizing cells after moving boxes, dying of boxes according to fleet type, writing base or line below the boxes, counting days, reproducing new checks and counting daily checks are completely removed. All these operations were the most time consuming steps of the creating maintenance plan and presently; they are produced automatically.

Human can make mistakes and so program should have control on process. The most dangerous mistake of line maintenance planning is missing aircrafts hours, having an overdue maintenance, and causing an unsafe flight. Program checks the remaining hours and if it is below the parameter sheet daily utilizations a message taken. If there is confusion in the format of data sheet or an undefined aircraft, another warning message is taken.

There are special cases that cause mistakes in plan. For instance, multiples of 10 checks of B737-800 are performed in a day and require some arrangement in official schedule accordingly; this has to be known before a week. Program automatically extends this special occasions making them realized.

The developed software is user friendly and also very flexible. New aircrafts are easily added without any code change so user does not have to have programming capability. Beside this, initially, after preparing maintenance plan it had to be faxed or mailed to the other departments as a excel document. Now just a link of plan is sent to the users reducing mail system storage requirements.

- Reduced cycle time
- Reduced mistakes on plan
- Improved customer satisfaction.

Lean thinking is a journey. That is to say, improvements and eliminating waste is not finished. There is still possibility of changing. Namely, automatic data flow can be provided. Consequently, planning process will be shortened for 15 minutes. As lean thinking is a philosophy of continuous improvement, there will be always enough room for new enhancements.

7.8. Expected Cost Benefits of the Lean Planning Process

Efficient and effective aircraft maintenance is vital for safety reasons, and is crucial revenue driver since airlines earn revenue when planes are in the air, not when on the ground **(Rouse, 2002).** MRO costs are corresponding to 12% of the total operating costs of an aircraft. During maintenance of commercially used aircrafts the owner faces high opportunity costs. The cost of having planes idle during unplanned maintenance is estimated at US-$ 23,000 per hour **(Brown, 2003).** Another study calculates this number as $50,000 for each hour **(Ghobbar and Friend, 2003).** For these reasons competitive advantages can be achieved by carefully planning maintenance events and making the execution of MRO more efficient **(Lampe et al, 2004).**

Table 7.1 shows the performance of the year 2005 and the realized number of maintenance. Maintenance interval utilization performance only analyzed for B737 series. This is because of underlining the importance of this type. B737 series are increasing in number. They constitute 50 % of the THY fleet. A little performance growth will cause big cost saving because Line maintenance is the most labour intensive MRO activity **(Stewart, 2005).**

The third column, 2005 yield shows interval utilization ratio which is calculated through the formula 7.1. This means that the average flight hour for L checks of B737-800 is 228 F/H. If the aircraft had been flight 250 F/H for each L checks, number of L checks in 2005 would have been 376 instead of 413.

It is impossible to perform Letter checks exactly on time because of daily flight schedules, unscheduled faults, hangar space limitation, outside station limitation, available technical personnel and some other reasons. On the other hand, targeted yields below the table could be realized by the new developed planning program implementation partly. Improvement in planning can be seen in Table 5.1. It is possible to realize it by operation research techniques. If the targeted yields had been performed in 2005 for L checks, then 17 unnecessary L check would not be done.

Table 7.1 Comparisons of realized and expected number of maintenance activities on targeted yields.

Fleet	Check Type	2005 Yield	Realized number of maintenance (2005)	Ideal Number on 100% yeild	Targeted Yield	Expected number of maintenance	Improvement
B737-800	A	94%	206	194	97%	200	6
B737-800	L	91%	413	376	95%	396	17
B737-400	A	85%	331	281	93%	302	29

An 738 A check cost is $11.700 -- benefit will be 11.700* 6 = $70.200

An 738 L check cost is $3.500 -- benefit will be 3.500*17 = $59.500

An 734 A check cost is $5.760 -- benefit will be 5.760*29 = $167.040

TOTAL BENEFIT = $296.740

The total profit of just better planning is $296.740 for the year of 2005. If other letter checks and other fleets included in this calculation, a huge number will be seen. Moreover, keeping aircraft on the ground for unnecessary maintenances cause to lose opportunity cost.

Instead of these 52 maintenance operations, pessimistically, 35 (go & back) extra revenue flights could have been performed. Let's say $60 revenue for each passenger and there are 100 passengers (50 passengers on each aircraft which can carry 150 passengers) on the flights, summer time this number will be much better.

The opportunity cost of extra flights:

35 extra flight * $60 revenue/passenger * 100 passenger = $210.000 revenue

- Airlines want to perform maintenance over the night, because there are not many flights. Not keeping aircrafts on ground will give extra hangar space and so, hangars can be used for customer's aircrafts. A nightly A check brings in 7000-17000$. Just renting hangar space for six hours is 2000$. Let say 5 extra A checks performed and 2 customer rent the hangar.

The opportunity cost of hangar space: $10.000 * 5 A check + 2 * $2000 = $54.000

Other advantages of not performing unnecessary maintenance:

- Less maintenance activity to plan, easy planning
- Less paperwork for work package
- Less personnel requirement

59 aircrafts are coming to THY fleet by end 2008 to 100 aircraft, mostly narrow bodies **(Buyck, 2005).** If we think about this, the importance of maintenance planning easily understood.

8. KEY PERFORMANCE MEASURES

Performance measurement is the process of quantifying action and can be defined as the efficiency and effectiveness of action. It focuses on the central issues of the business which are usually cost, quality, delivery people, and suppliers **(Davies and Greenough, 2002).** Key performance parameters should reflect factors that affect performance.

How does an enterprise know if it is "Lean"? Benchmarking oneself against best internal operations can be one measure of the relative value of one's leanness. In addition, appropriately chosen metrics are the performance characteristics that are used to assess whether or not an enterprise is lean **(Mathaisel et al, 2004).** The tables blow (Table 8.1, 8.2, 8.3, 8.4 and 8.5) suggests performance parameters to evaluate THY Technic performance.

Table 8.1 : Performance parameters for MRO Leadership

Measure	Target	Frequency
Aircraft delays due Technic	reducing trend	3mth
Average length of AOG due Technic	reducing trend	3mth
Labour productivity	improving trend	3mth

Table 8.2: Performance parameters for Engineering Department

Measure	Target	Frequency
Flow time for AD assessment	10days	3mthly
Flow time for SB assessment	2mths	6mthly
Flow time to release MPD revision	2mths	6mthly
Data integrity	improving trend	3mthly

Table 8.3: Performance parameters for Aircraft Maintenance - Base

Measure	Target	Frequency
% checks delivered to plan TAT (days)	95%	Monthly
Hangar dock utilization	100%	Monthly

Table 8.4: Performance parameters for Aircraft Maintenance - Line

Measure	Target	Frequency
On time performance (Tech delay rate)	98%	Monthly
MEL items/clearance time	<4 per fleet/3days	Monthly
No of deferrals carried	1 per aircraft (avg.)	Monthly

Table 8.5: Performance parameters for Production Planning and Control

Measure	Target	Frequency
Plans issued and updated/revised by due dates	100%	Monthly
Maintenance check TAT - plan vs actual	5%	Every Check
Maintenance check man-hours - plan vs actual	5%	Every Check
Work Package Call-up completion (all)	96%	Every Check
Work Package Call-up completion (scheduled)	100%	Every Check
Incidence of AD or EO overdue	0%	Weekly
Tasks added after Work Package Closed	0	Every Check
Check Interval % Life Achieved (light)	90%	Every Check
Check Interval % Life Achieved (heavy)	95%	Every Check
Time Controlled Component % Life Achieved	97%	Monthly
Bill of Materials accuracy	100%	Every Check
Removal of EO after cut-off	5%	Every Check

9. CONCLUSION

The concept and use of lean thinking refers to the total enterprise and is aimed at adding value to an organization through the elimination of waste. Competitive environment have led airlines to evaluate their process and organizations completely. Lean thinking creates “more and more with less and less” by focusing on eliminating waste, decreasing cycle times, increasing productivity, achieving world class performance, improving quality and sustainable competitive advantage **(Womack and Jones, 1996) (Francis, 2005).** An aircraft operator can incur costs of more than $50,000 for each hour if a plane is on the ground. Also, maintenance costs are increasing by the complexity of the aircraft. Therefore, aircraft have to fly as much as possible.

However, it was recognized from the start that a large number of airline companies in Turkey still used earlier methods. The evaluations in the study were made for aircraft maintenance system development which had previously received little attention. They clearly show that traditional planning, forecasting and controlling techniques mentioned above are need to be reviewed by lean thinking.

Many of the recommended function and process improvements are at least partially dependent on a substantial improvement in the IT support. This inevitably means that there is a requirement to accomplish extensive software upgrades to the current system or for the replacement of the current system with a new generation fully integrated system in order for these recommended improvements to be fully effective.

Much of the cost benefit of installing such a system will come from the enabling technologies such as bar coding and a general move to discourage paperwork. This movement is gaining momentum across the industry as the availability of web based data increases. Updated IT will improve maintenance productivity and reduce inventory. The ERP installation will further influence the functionality as the essence of the system is to see data entered once only, yet made available to everybody who needs to have access to it.

All planning should be based on use of an integrated IT planning tool and all primary source data should be taken from the integrated IT system. All plans should be available electronically and real-time to all end users, existing IT System needs to be upgraded to hold all required source data and the process of updating should be as close to real-time as is practical with single data entry of all data. An immediate improvement is required in the data integrity.

There are disconnects between Line and Base as to the work carryovers from the Line operation to the Heavy maintenance operation. The result is additional work becoming known during the progress of the Check. A better coordination and interface with Line maintenance will be sought by Base management to ensure that required work on the Check as a result of Line is achieved. Base will also be sensitive to the Line operation and will attempt to deliver a clean aircraft, no carry over or deferral items, to Line.

Finally, this research has shown that the level of appropriate factors has an effect on the planning performance. It is possible to decrease turn around time 85%, freeing up 3 hours. If this remedy combined with other departmental improvements, it is possible to save hundreds of dollars. The study has presented a model that could be of good benefit to airline operators and other maintenance service organizations. It will enable them to decrease to opportunity cost and better meets their demands. Further research will focus on combining the developed software with operations research techniques. This study has taken a step in the direction of defining the relationship between planning and lean thinking. Although I have used data from one particular airline operator, it is suggested that these findings may be applicable elsewhere as other industrial sectors have similar demand patterns to airlines.

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APPENDIX A

Table A.1: Defining daily aircraft utilization for B737-400.

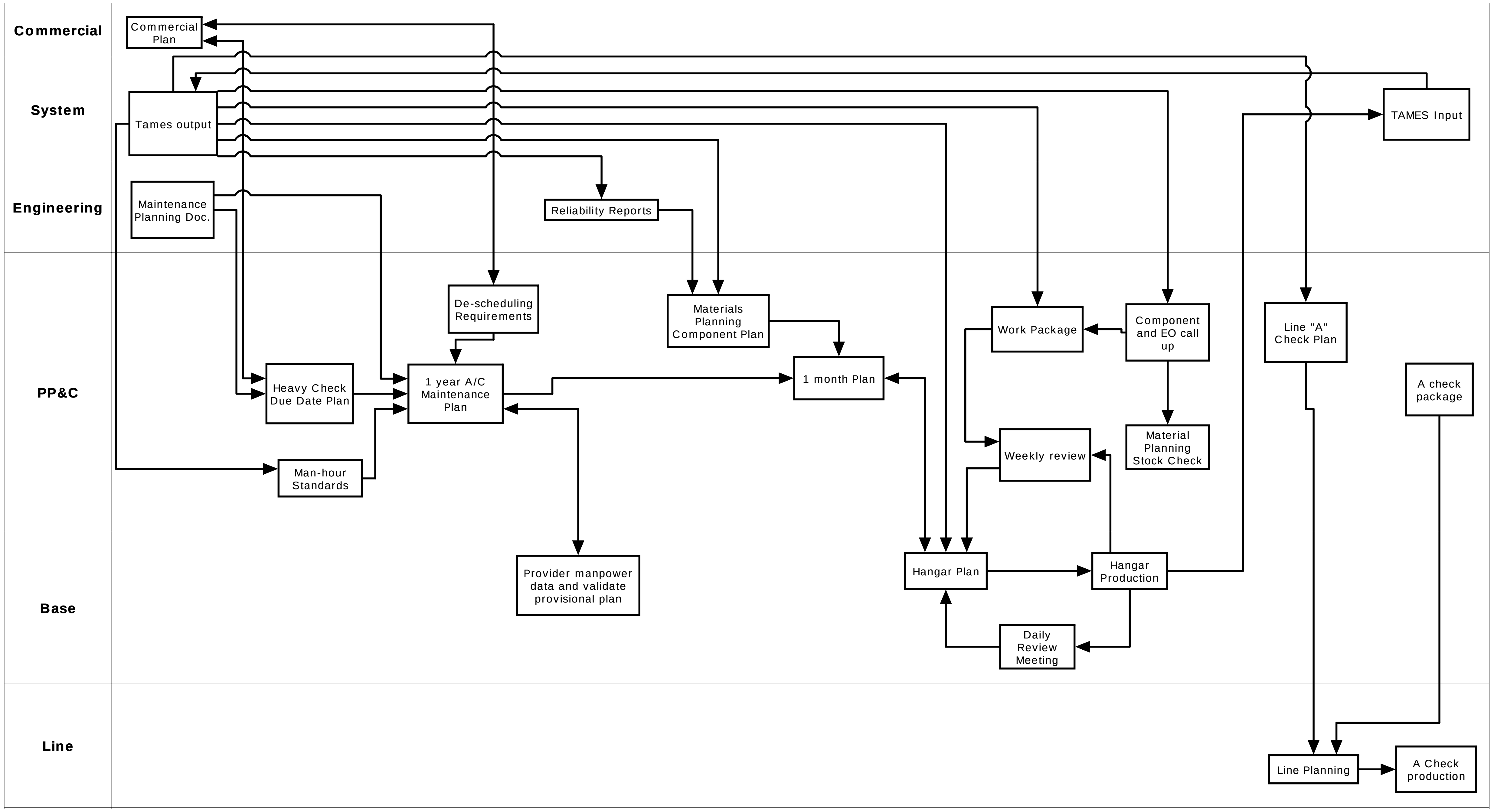
Calculation of Aircraft Daily Utilization

734	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	Av of months	Max	Min	SD	Summer Season	Winter Season
	2004				2005													
JDF	6,4	6,2	6,9	5,3	6,5	6,6	6,9	6,8	5,8	8,3	8,3	8,5	6,9	8,5	5,3	1,0	9	7,0
JDG	4,7	4,8	7,7	7,5	6,9	6,9	6,7	7,7	7,3	7,4	7,5	8,1	7,0	8,1	4,7	1,1	9	7,0
JDH	6,7	5,1	7,1	7,8	5,9	6,1	6,7	7,6	7,5	7,5	8,7	7,7	7,0	8,7	5,1	1,0	9	7,0
JDT	4,4	7,2	7,0	6,9	6,4	6,7	7,2	7,7	7,5	6,6	8,8	8,5	7,1	8,8	4,4	1,1	9	7,0
JDY	3,5	6,9	7,3	7,0	7,0	6,7	7,0	7,2	7,4	5,8	8,2	8,5	6,9	8,5	3,5	1,3	9	7,0
JEN	6,0	6,6	7,1	7,0	6,4	7,3	6,3	7,3	6,5	8,9	8,4	7,9	7,1	8,9	6,0	0,9	9	7,0
JEO	6,9	5,4	7,1	7,1	7,1	7,3	6,3	6,4	7,2	7,3	8,5	8,8	7,1	8,8	5,4	0,9	9	7,0
JER	7,7	7,6	6,2	7,0	5,6	6,9	6,5	8,1	8,0	7,4	6,5	0,0	6,5	8,1	0,0	2,2	9	7,0
JET	6,1	6,5	6,5	5,9	7,1	7,1	6,0	7,3	7,9	8,0	2,9	5,1	6,4	8,0	2,9	1,4	9	7,0
JEU	6,7	7,1	5,2	7,3	6,3	6,0	6,7	5,9	8,2	7,4	8,4	8,5	7,0	8,5	5,2	1,0	9	7,0
JEV	6,7	7,2	7,1	6,6	5,2	4,8	6,3	7,1	7,4	7,6	8,3	7,3	6,8	8,3	4,8	1,0	9	7,0
JEY	7,1	6,1	7,5	7,4	7,1	4,6	6,4	7,2	3,2	7,1	7,7	9,0	6,7	9,0	3,2	1,5	9	7,0
JEZ	7,5	7,7	3,3	6,8	6,6	5,8	6,7	7,2	7,9	7,8	7,4	7,1	6,8	7,9	3,3	1,2	9	7,0
JKA	5,8	5,3	7,3	6,4	7,1	6,2	6,6	7,1	7,4	7,9	8,5	5,4	6,7	8,5	5,3	1,0	9	7,0
JKB	6,5	5,9	6,0	4,5	4,3	5,4	5,8	6,9	6,8	7,1	7,3	6,7	6,1	7,3	4,3	1,0	7,5	6,0
JKC	7,5	6,5	6,1	5,8	5,1	5,4	5,8	6,6	7,2	7,0	7,3	6,3	6,4	7,5	5,1	0,8	7,5	6,0
JKD	6,5	7,3	5,8	6,0	5,2	5,6	6,1	5,9	6,8	5,7	6,7	6,6	6,2	7,3	5,2	0,6	7,5	6,0
Ort	6,3	6,4	6,6	6,6	6,2	6,2	6,5	7,1	7,0	7,3	7,6	7,1	6,7	8,3	4,3			

Table A.2: Defining daily aircraft utilization for B737-800

738	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	Av of months	Max	Min	SD	Summer Season	Winter Season
	2004				2005													
JFC	10,9	10,9	9,4	9,1	9,2	9,9	9,2	10,7	11,0	9,3	11,8	**11,8**	10,3	**11,8**	**9,1**	1,0	12	9,6
JFD	11,3	11,2	9,3	8,5	7,7	9,7	9,2	10,4	11,0	11,6	11,8	**12,0**	10,3	**12,0**	**7,7**	1,4	12	9,2
JFE	10,3	9,9	10,3	8,1	11,1	9,1	9,0	11,3	11,3	10,3	12,1	**8,9**	10,2	**12,1**	**8,1**	1,2	12,1	9,6
JFF	10,8	8,6	9,0	9,8	9,7	8,2	9,3	9,0	11,1	11,1	10,8	**11,0**	9,9	**11,1**	**8,2**	1,1	12	9,1
JFG	11,3	10,4	8,7	9,0	9,6	9,6	9,6	10,2	10,7	11,2	11,5	**11,1**	10,2	**11,5**	**8,7**	0,9	12	9,5
JFH	10,8	10,2	9,0	10,4	9,4	8,3	11,2	10,5	10,8	11,1	11,1	**11,2**	10,3	**11,2**	**8,3**	1,0	12	9,7
JFI	9,9	8,9	9,8	8,8	10,7	9,4	9,3	10,8	10,1	10,6	11,5	**11,3**	10,1	**11,5**	**8,8**	0,9	12	9,5
JFJ	10,5	9,2	9,7	9,5	8,8	8,9	8,1	10,9	11,5	11,9	11,7	**12,1**	10,2	**12,1**	**8,1**	1,4	12,1	9,0
JFK	10,8	9,5	8,6	9,0	9,5	9,0	8,2	8,7	10,7	10,6	9,8	**9,5**	9,5	**10,8**	**8,2**	0,9	11	9,0
JFL	11,1	10,8	9,9	9,5	8,8	9,3	10,2	4,4	9,1	12,2	12,3	**11,6**	9,9	**12,3**	**4,4**	2,1	12,3	9,7
JFM	10,8	9,8	9,0	9,1	9,4	7,9	9,8	9,7	7,8	12,5	13,0	**10,7**	10,0	**13,0**	**7,8**	1,6	13	9,2
JFN	11,8	11,1	9,1	9,1	10,1	10,3	8,7	8,8	8,2	11,6	13,0	**11,7**	10,3	**13,0**	**8,2**	1,6	13	9,7
JFO	9,0	10,5	9,2	7,3	9,3	9,2	9,1	10,4	11,0	11,6	7,0	**11,7**	9,6	**11,7**	**7,0**	1,5	12	9,1
JFP	11,3	10,4	9,4	8,8	10,8	9,1	9,1	10,6	9,9	8,3	10,2	**13,2**	10,1	**13,2**	**8,3**	1,3	13	9,6
JFR	9,9	10,9	9,0	9,6	10,4	8,0	10,0	10,5	10,7	10,8	12,7	**11,7**	10,4	**12,7**	**8,0**	1,2	12,5	9,6
JFT	12,1	11,6	11,5	9,3	10,9	10,9	10,1	10,7	12,7	7,5	11,7	**11,2**	10,9	**12,7**	**7,5**	1,4	12,1	10,7
JFU	11,9	10,4	10,4	9,5	8,1	9,9	9,5	9,6	9,9	11,1	12,0	**12,0**	10,4	**12,0**	**8,1**	1,2	12	9,6
JFV	11,0	10,3	9,1	9,3	9,7	8,1	9,4	10,5	11,5	10,7	10,9	**8,2**	9,9	**11,5**	**8,1**	1,1	12	9,3
JFY	11,4	11,4	10,1	9,7	9,5	8,9	10,0	9,7	11,2	9,8	11,4	**11,3**	10,4	**11,4**	**8,9**	0,9	12	9,9
JFZ	10,7	10,6	9,7	10,3	9,5	9,9	10,9	11,0	9,7	12,2	11,7	**10,9**	10,6	**12,2**	**9,5**	0,8	12	10,1
JGA	10,9	11,1	9,7	8,5	10,5	9,4	9,8	11,1	10,5	11,4	11,8	**13,0**	10,7	**13,0**	**8,5**	1,2	13	9,8
JGB	10,1	10,0	9,5	9,7	10,2	9,4	9,2	11,3	10,6	11,2	12,0	**13,1**	10,5	**13,1**	**9,2**	1,2	13	9,7
JGC	10,6	10,4	9,8	9,3	9,9	9,0	10,2	10,1	9,8	12,7	11,6	**9,5**	10,2	**12,7**	**9,0**	1,0	12,5	9,8
JGD	12,2	10,1	9,0	9,7	8,7	9,2	9,6	9,4	10,0	11,4	11,7	**9,5**	10,0	**12,2**	**8,7**	1,1	12,5	9,4
JGE	12,6	12,2	11,5	10,1	11,2	11,0	11,4	11,4	11,5	12,0	13,4	**12,2**	11,7	**13,4**	**10,1**	0,8	13,2	11,2
JGF	12,3	12,5	11,4	11,7	11,5	10,9	11,7	13,1	11,9	12,2	12,3	**12,6**	12,0	**13,1**	**10,9**	0,6	13	11,6
Ort	11,0	10,5	9,7	9,3	9,8	9,3	9,7	10,2	10,5	11,0	11,6	11,3	10,3	12,2	8,4			

APPENDIX B


Commercial
System
Engineering
PP&C
Base
Line
Commercial Plan
Tames output
TAMES Input
Maintenance Planning Doc.
Reliability Reports
De-scheduling Requirements
Materials Planning Component Plan
Work Package
Component and EO call up
Line "A" Check Plan
A check package
Heavy Check Due Date Plan
1 year A/C Maintenance Plan
1 month Plan
Weekly review
Material Planning Stock Check
Man-hour Standards
Provider manpower data and validate provisional plan
Hangar Plan
Hangar Production
Daily Review Meeting
Line Planning
A Check production

APPENDIX C

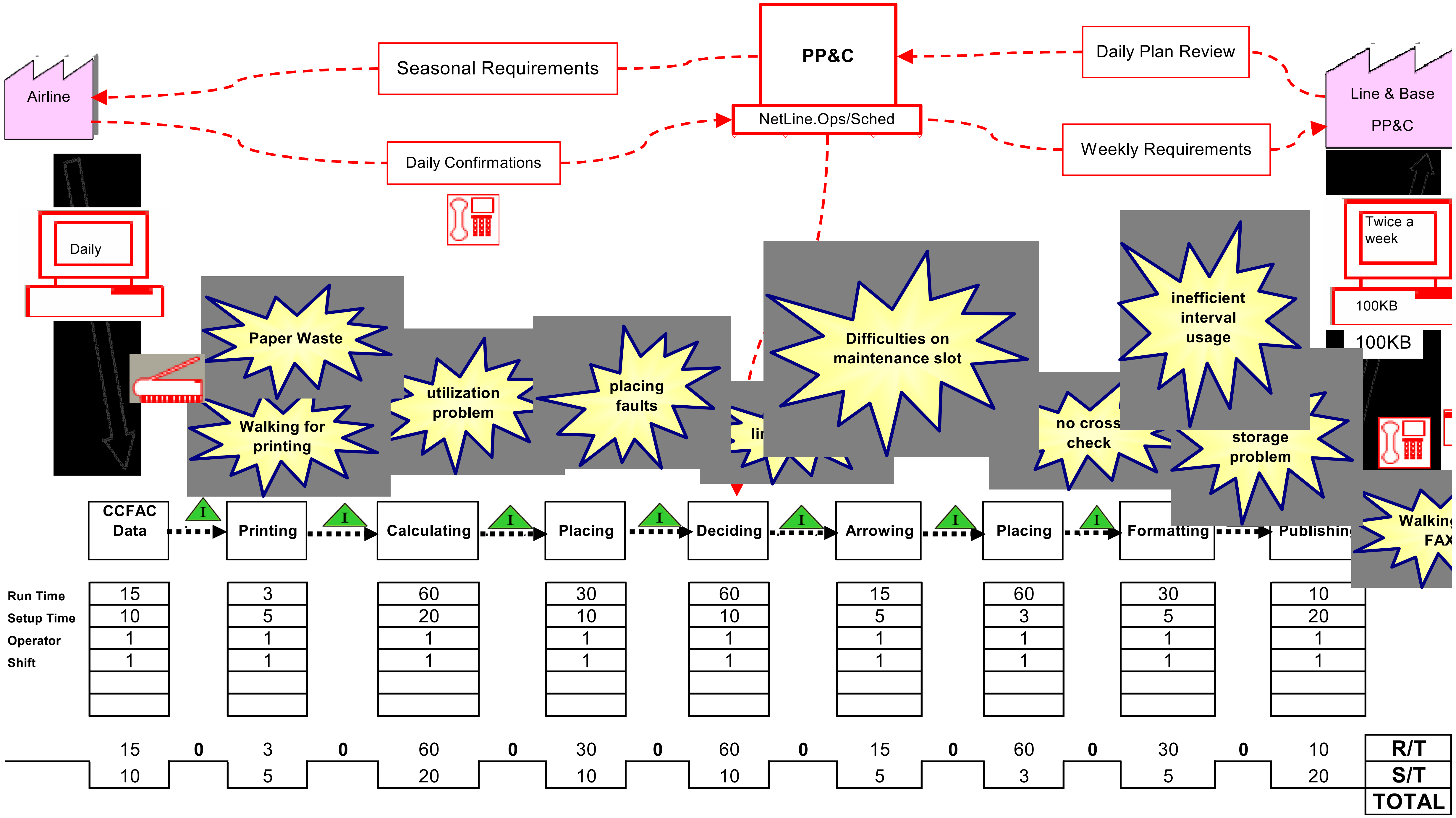


Figure C.1: CURRENT STATE VALUE STREAM MAP OF LINE MAINTENANCE PLANNING

Curriculum Vitae

Feray Günseli Demiral (Ersever) was born in Bursa, in 1980. She graduated from Istanbul Technical University with a degree in Environmental Engineering, with the best GPA: 3,71 in 2003. She also earned a degree in Industrial Engineering in 2004. She has been working for Turkish Airlines, Production Planning & Control Department, as a Planning Engineer for 1,5 years.

She plays badminton and likes walking by the bosphorus. She has been married for one year and has a cat named Çakıl.