THE REPUPLIC OF TURKEY
BAHCESEHİR UNIVERSITY

VALUE STREAM MAPPING IN LINE MAINTENANCE

Master's Thesis

FEHMİ ÖZTÜRK

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THE REPUPLIC OF TURKEY
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This is to certify that we have read this thesis and we find it fully adequate in scope, quality and content, as a thesis for the degree of Master of Arts.

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ABSTRACT

VALUE STREAM MAPPNING IN LINE MAINTENANCE

Fehmi ÖZTÜRK

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Today's airlines place emphasis on-time departure which is a master key for the flight operation. From daily checks to the handling of spare parts, line maintenance services provide the basis on which to build the reliable flight schedule that is the top priority of an airline. When facing the unexpected, you can rely on the line maintenance expertise and rapid reaction to get an aircraft back in the air in the shortest possible time.

An airline must have well capacity line maintenance organization to meet the requirements for on-time departure.

Line Maintenance generally refers to minor, unscheduled or scheduled maintenance carried out on aircraft that includes Pre-flight, daily, weekly, and ETOPS(Extended Twin Engine operations) checks, On-call maintenance, AOG(Aircraft on Ground) recovery and field team assistance, technical assistance, trouble rectification, spare parts and component logistics to maintain the flight operations.

Line maintenance become more significant for the airlines with the increasing flight numbers and fleet size. Consequently, most airlines should take account of improving their line maintenance capacity and organization.

The objectives of this project are to analyze an airline's line maintenance activities and processes and identify the problems, and enhance the line maintenance capacity and operation with using VSM methodology.

Keywords: VSM, Line Maintenance Capacity, Business Process Improvement, Lean Production

ÖZET

HAT BAKIMDA DEĞER AKIŞI HARİTALANDIRMA

Fehmi ÖZTÜRK

Endüstri Mühendisliği

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Günümüz hava yolları uçuş operasyonları için en önemli etken olan zamanında kalkışa büyük önem vermektedirler. Günlük bakımdan, malzeme ihtiyacına kadar, Hat Bakım, Hava yollarının en önemli önceliği olan güvenilir uçuşun en büyük teminatıdır. Beklenmedik bir durumla karşılaşıldığında Hat Bakım, uçağı tekrardan uçuşa döndürebilmek için en kısa sürede uçağa müdahale edecek tecrübeye sahiptir.

Bu yüzden bir Hava yolu zamanında kalkış yapma ihtiyacını karşılayabilmek için iyi bir kapasiteye sahip Hat Bakım organizasyonuna sahip olmalıdır.

Hat Bakım genellikle ufak, planlı ve plansız, uçus öncesi ve sonrası, günlük-haftalık bakımların yapıldığı, bunların yanında uçağın acil durumlarında her zaman destek veren, arızaları gideren, bir teknik birimdir.

Artan uçak ve sefer sayıları ile birlikte, Hat Bakım'ın önemi de doğru orantılı olarak artmıştır. Buna istinaden MRO firmaları Hat Bakım organizasyonlarında kapasitelerini arttırmak adına iyileştirici faaliyetler yapmak zorundadırlar.

Bu çalışmanın amacı da yalın üretim araçlarından biri olan değer akışı haritalandırma yöntemini kullanarak bir Hat Bakım organizasyonun ele alınması ve tüm süreçlerinin analiz edilerek, operasyonunun ve organizasyonun kapasiteni arttırmak.

Anahtar Kelimeler: Değer Akışı Haritalandırma, Hat Bakım, Süreç İyileştirme, Yalın Üretim

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

A/C	:	Aircraft
AOG	:	Aircraft On Ground
CSM	:	Current State Map
EASA	:	European Aviation Safety Agency
ETOPS	:	Extended Twin Operations
FAA	:	Federal Aviation Administration
FAR	:	Federal Aviation Regulation
FSM	:	Future State Map
ICAO	:	International Civil Aviation Organization
IFE	:	In Flight Entertainment
JAR	:	Joint Aviation Regulation
LM	:	Line Maintenance
M	:	Mean
MRO	:	Maintenance Repair Overhaul
SD	:	Standard Deviation
VSM	:	Value Stream Mapping
XSIT	:	Extended Sterile Insect Technique

1. INTRODUCTION

This thesis presents an investigation into Value Stream Mapping (VSM) technique for the reorganization of line maintenance of a Maintenance Repair Overhaul (MRO) company in aviation industry.

MRO means maintenance, repair and overhaul. The definition of MRO is used in a lot of industry but mainly used in aviation industry. In order to maintain, repair and overhaul in aviation, it is necessary to gain capability and required approval from EASA or FAA. According to the regulation of FAA, MRO can do maintenance, overhaul, repair and the replacement of aircraft parts with the approval of authority. (FAA, 2012)

MRO is a very big operation that has very complex process limited by airworthiness authorities to assuring aircraft safety and airworthiness which defines as a confirmation to the regulations under which a certified aeronautical product.

According to MRO industry statistics, global MRO market size in 2015 is nearly $67.1 billion and the market share by MRO segments are respectively airframe (22 percent), engine (42 percent), component (19 percent) and line maintenance (18 percent). (Doan, 2015)

While airframe, engine and component maintenances are simple and scheduled, line maintenance is very complicated. Because of having various scope of work, line maintenance is essential and crucial for the Airline fleet.

Line maintenance organizations are mainly required to provide necessary support to the aircraft fleet on ground and in flight for 7 days 24 hours. Therefore, it is the most important and major operation in aircraft maintenance.

Line Maintenance generally refers to small, planned or unplanned maintenance (Williams, 2016). Line Maintenance includes various maintenance services such as repetitive checks (Transit, daily, weekly, ramp and A checks), servicing, troubleshooting, ground operations, cabin interior and in-flight entertainment services and more. Because of this wide range of services and very busy aircraft scheduling, Line maintenance must be well organized to keep the aircrafts safe and reliable for the flights. In order to make a well organization in such a complex area the several workflows should be minimized.

The goal of this work is to eliminate the waste in the process of line maintenance and to reorganize the structure more efficiently. The elimination of waste, particularly in terms of time, manpower, overproduction of products and systems interruptions, should be a major concern for any business. In order to reduce the maintenance costs and to increase the service capacity, a MRO must have some additional methods for eliminating waste and have a constant reorganization to keep the aircraft scheduling on time. At this point, Lean thinking which provides a special view point for eliminating the unnecessary action might be useful to solve this problem. Lean method diverts the loss of energy to the other process which requires more energy than it has. The lean thinking is also very good alternative to redefine the work of scope from every aspect in the departments of the operation.

Even though lean seems like more philosophical approach, it is also practical and project based. Neither of the approaches is more correct than the other, since lean exist at both level, having both strategic and operational importance (Hines, 2004). Many tools and principles have been developed by taking these approaches into consideration to improve each individual process and define the real needs of employee or work in production or in service. One of the lean tools used by the industry is value stream mapping (VSM). VSM is a lean manufacturing tool which first analyses the all process and then eliminates the waste in the organization. It has been standardized for years mostly in automotive industry as an important utility tool which has some principles and guidelines to create a valuable improvement on the process. It is accepted the one of best demonstration tool for the individual process with the specific concerns in the operation.

Because of having various benefits such as highlighted dependencies, identified opportunities for the application of specific tools and strategies, improved understanding of highly complex systems, synchronized and prioritized continuous improvement activities, VSM is very suitable for implementing on line maintenance environment. In addition to these benefits, VSM provides a common language to communicate between managers, engineers, suppliers and customer who are familiar to recognize different forms of waste and its sources (Thiruvengadam, 2004).

Even though there are a lot of valuable VSM applications used in aviation, these applications do not offer any specific guidelines on line maintenance service which is differ from standard production.

While very few studies concentrate on the MRO industry, the majority of the studies described and analyzed product and information flow in the supply chain of the MRO industry.

Some of studies deal with employee and maintenance scheduling in order to gain time efficiency; other is specifically more focused on adopting lean as a business strategy in the MRO industry.

Very few of magazine and article have mentioned about VSM to analyze and improve the line maintenance organization.

Therefore the research is considered to be relevant as it defines and applies VSM for line maintenance capacity improvement in MRO industry where no similar research was performed from an internal perspective. The research intends to demonstrate a real case study in line maintenance organization with experimental data source which has been obtained by the line maintenance personnel.

The first problem of this research is to collect a real data of line maintenance process for improvement and eliminating the wastes.

The second problem is to demonstrate a real case application for wide range of services in line maintenance.

First of all it is necessary to define the research environment and the line maintenance services. As far as the research problem is formulated for a MRO industry, it is important to identify how appropriate VSM approach is for line maintenance improvement in MRO industry? And what are the most important factors to implement a VSM method for the line maintenance operation?

Second, it is necessary to demonstrate how can VSM be adjusted for the unscheduled and scheduled maintenance services in line maintenance or MRO industry?

Within these research questions the thesis analyzes each step of individual process that is really importance on line maintenance and identifies every single service that could be improved with VSM method.

Null Hypothesis (H_0); there will be no significant difference between actual situation and future situation after using VSM method in line maintenance process. It means that there will be no valuable improvement.

Alternative Hypothesis (H_a); there will be significant difference between actual situation and future situation after using VSM method in line maintenance process. It means that there will be no valuable improvement.

1.1 OPERATIONAL DEFINITIONS

In order to understand the overall scope of work in line maintenance, following terms and phrases will be generally defined.

Operational Definitions;

Heavy (Base) Maintenance: This can generally be defined as maintenance activities falling under C Checks and D checks (JAR-145 Section 2 paragraph 3.2.3), requiring panel and access doors opening and disassembly for deeper inspection and eventually repair. Base maintenance is mainly characterized by long downtime periods and large maintenance packages, quantified in terms of man-hours

Schedule Maintenance: Maintenance is scheduled at specific pre-determined intervals (flight hours/cycles) and corrective action is taken to ensure the safety of the airplane until the next scheduled maintenance.

Unscheduled Maintenance: Maintenance is requested when the damage becomes threatening to safety.

Pre-flight Check: Check applied before the departure of aircraft, to perform visual and functional inspection.

A Check: It is the smallest letter check in the literature. It is performed with certain interval based on the flight hour or flight cycle of the aircraft. The duration of A check is determined according to the type of aircraft. The first A check may take nearly 24 hour.

Visual Check / Operational Check: It is on condition check. If there is a defect observed from pilot or technician, this check could be requested.

Ramp Check: This check is also on condition check. However, it is requested upon a major and critical problem which could make the aircraft unserviceable. It may be planned or unplanned depends on the decision of airline operator.

Transit Check: After/ before each flight a transit check has to be performed. It is must do item and walk around inspection. In case of necessity the related maintenance action has to be performed.

In Flight Entertainment: It refers to the entertainment available to aircraft passengers during a flight. The service offers movies, music, games, live tv, internet, application by depending the service quality of the airline.

De-icing: It means anti icing and it removes and protects the aircraft surface, and the parts of aircraft flight controls from ice.

X-sit: Sterile Insect Technique provides effective, environmentally safe control in citrus, pomegranates and various deciduous varieties.

ETOPS: It means Extended Range Operation with Two-Engine Airplanes. It is a standard by ICAO in order to fly to long distance, especially for the intercontinental flights routes

AOG: It means aircraft on ground. In order to enter an aircraft to the service, AOG team or group behaves like a help desk which is responsible to find a required component and spare parts for the aircrafts.

2. LITERATURE REVIEW

The primary focus on the literature analysis tends to be centered on value stream mapping methods for line maintenance in MRO industry. Within the principle of lean thinking, specifying value accurately is the critical first step (James P.Womack, 2003).

Lean thinking was born from Japanese culture and created by one of the Japanese leading automotive company; Toyota targeted to eliminate the loss in the production where two major mottos were very common such as just in time and Jidoka whose synonym is autonomation (Liker, 2004).

At the beginning, some researchers have mainly focused on just-in-time because of having substantial benefits (Kodali & Jasti, 2014).

Unless it is real necessary, the stocks has to be reduced, and if there is a real need, then the products should be produced as much as requisite (S.Tiwari, Dubey, & Tripathi, 2012).

The just in time technique has been used for years in auto industry. It has extremely attained very good reputation as a successful technic which provide an improvement while eliminating the wastes.

These two major pillars of Toyota production system became more popular and recognized the term of lean production.

Just in time manufacturing system has been reviewed and presented in many research as a lean thinking concept. For example, the research by (1995) is quite improving. They found important elements of successful just-in-time implementation with over than 40 sample articles. Their objective was to compare the past and current research about just-in-time manufacturing system from different aspects (Zhu & Meredith, 1995). Ramarapu, Mehra, and Frolick (1995) defined important just in time application with the sample of more than 100 articles. They analyzed different research method and just-in-time implementations.

After every theoretical and practical implementation, just-in-time philosophy went one step further. The ideas in just in time philosophy gained acceptance and spread auto industry. Later, the just in time and Jidoka concept had been placed in lean theory as two major elements. Lean thinking became more and more popular at the beginning of 1990. Many different technologies and manufacturing techniques were developed from lean thinking perspective (Womack, T.Jones, & Roos, 1990).

The similar concept appeared in the article by Krafcik (1998). The article was again about auto industry and was mentioned the effect of Japanese lean thinking on American auto industry.

In the 1990's most of the articles and book had been written and nearly all methods had been implemented about lean production were in order to develop automobile production line.

The achievements in the auto industry as a consequence of lean production was so critical and they led the other organization in any industry encourage for applying lean methods. Lean production concept had spread across the industrial landscape, including service organizations.

Womack and Jones had been collected many examples of small firms to giants of industry, low-volume producers to contrast with high volume automakers, and high-tech firms to compare against with those classical technologies. At the end of this period they gained a deep understanding of the needs for every organization in every industry. As a consequence of this deep research, five lean principles were summarized. These principles briefly are value, value stream, flow, pull and perfection. By clearly understanding these five principles, and tying them all together, lean techniques could be fully apply to any organization (James P.Womack, 2003).

These five steps which are seen in table 2.1, are also defined by Dr. Hugh L. McManus (2005).

1. Precisely specify **value** by specific product
2. Identify the **value stream** for each product
3. Make value **flow** without interruptions
4. Let the customer **pull** value from the producer
5. Pursue **perfection**

Table 2.1: Applying 5 Lean Steps

	Manufacturing	Engineering
Value	Visible at each step, defined goal	Harder to see, emergent goals
Value Stream	Parts and material	Information and knowledge
Flow	Iterations are waste	Planned iterations must be efficient
Pull	Driven by takt time	Driven by needs of enterprise
Perfection	Process repeatable without errors	Process enables enterprise improvement

Reference: Adapted from the book "Learning to see", by (Rother & Shook, 1999).

Lean production principles have been conceptually reviewed by many researchers and attained a valuable place in the literature. The principles are summarized in the book "Learning to see", by (Rother & Shook, 1999). The summarized principles can be seen in table 2.1.

Table 2.2: Lean Principles

Framework	Principle
Process	1. Establish customer-defined value to separate value added from waste.
	2. Front load the product development process to thoroughly explore alternative solutions while there is Maximum Design Space.
	3. Create a leveled Product Development Process Flow.
	4. Utilize Rigorous Standardization to Reduce Variation, and Create Flexibility and Predictable Outcomes.
People	5. Develop a "Chief Engineer System" to Integrate Development from start to finish.
	6. Organize to balance Functional Expertise and Cross-functional Integration.
	7. Develop Towering Technical Competence in all Engineers.
	8. Fully Integrate Suppliers into the Product Development System.
	9. Build in Learning and Continuous Improvement.
	10. Build a Culture to Support Excellence and Relentless Improvement.
Tools and Technology	11. Adapt Technology to Fit your People and Process.
	12. Align your Organization through Simple, Visual Communication.
	13. Use Powerful Tools for Standardization and Organizational Learning.

Reference: Rother, M., & Shook, J. (1999). *Learning to see: Value stream mapping to create value and eliminate muda.* Lean Enterprise Institute.

However, there was also various criticism and clarification on lean production as in the case with the research made by Hines, Holweg, and Rich (2004). They provided a framework to find out the evolution of lean not only as a concept, but also its implementation within an organization, and drew an attention the available sectors for future research. Even though lean thinking had valuable effects both on industry and academy; it had been criticized on many aspects, such as the lack of human factor or the limited application in high volume repetitive manufacturing environments (P.Hines, Holweg, & Rich., 2004). At the Cambridge University Gill (2003) made a project that resulted with lean production increased worker turnover and accidents due to time pressure. Papadopoulou and Özbayrak (2005) carried out research which included overview of the lean philosophy and the results of literature survey for identifying the lean manufacturing elements, comparison with other manufacturing practices. The study showed absence of lean production applications among many sectors with the exception of manufacturing sector and the study also showed the necessity of development for lean principles (Papadopoulou & Özbayrak, 2005). Holweg (2007) reviewed the all literature and his research was based on the experience of colleagues in International Motor Vehicle Program. It also includes a timeline of the concepts which is cited from PICSIE Books written by Bicheno (2000).

One of the important principles in lean production is value stream which is defined as the work process from the view of actions (Stone, 2012). These are divided into three types such as value adding actions, necessary non value adding actions and unnecessary non-value adding actions (Monden, 1998). In the years these actions considered as a flow of process within the overall supply chain. To define every value adding steps in process, the needs of drawing maps have been arisen among the lean participants to view the big picture. Hines and Rich (1997) defined and described seven mapping tools. Afterwards Rother and Shook (2003) developed new value stream method with further approach from lean manufacturing. Value stream mapping (VSM) has been used to analyze the process for improvement through the frame of lean principles. VSM was seemed as a viewpoint to see every action to implement lean thinking (Chen & Shady, 2010). A research enlighten to lean maintenance while using VSM had been carried by Thirunvengadam (2004). The research developed a hierarchy for breakdown maintenance wastes and a framework containing key metrics.

There are many articles and case studies related to value stream mapping in literature, because of popularity and easy application to visualize and analyze the all activities in organization. VSM has been mainly used in manufacturing environment from the literature review.

There is a limited research about lean thinking and VSM in MRO industry. Only a few research has been found for aerospace industry such as the research conducted by Crute, Ward, Brown (2003). The articles published in aircraft maintenance sectors were very minimal. However, a book written by Smith, Ricky, Hawkins, Bruce (2004) was essential approach for lean maintenance. They clearly showed the integrating lean goals with maintenance goals. They defined the maintenance principles and objectives with details. This explanatory study guided for lean maintenance for every sectors. The proactive and reactive maintenance characteristic were deeply analyzed and defined in lean thinking concept. It is important that the maintenance operation's vision, its mission and its goals and objectives should be well distinguished (Smith & Hawkings, 2004). The similar study conducted by Shrinivasan, Bowers, Gilbert (2014) defined and described the lean thinking concepts have been applied to maintenance repair overhaul organizations in the commercial and defense sector.

A group of researcher Nanova, Dimitrov, Neshkov, Apostolopoulos, Savvopoulos (2012) carried out a specific study about lean application in an aircraft maintenance, repair, and overhaul. The paper gave an overview and provided customized examples to supply the needs of the specific maintenance tasks. However, the given examples are not enough in order to clarify the extent of lean production with details in such an unpredictable and unscheduled working environment (Nanova, Dimitrov, Neshkov, C.Apostolopoulos, & P.Savvopoulos, 2012).

The lean application for aircraft maintenance is challenging to apply all lean principle in a common way. Because of this reason the articles and researches in the literature could not define the lean implementation for specific aircraft maintenance. The characteristics of the MRO sector such as low volume of processed services, the non-routine work scopes, variable customer demand, and a large scale of maintenance tasks are a little bit different from mainstream of Lean literature (Brinkman, 2015).

Even though MRO sector is challenging era for implementing lean application, because of intense global competition MRO organizations have to take some additional maneuver to reduce the cost (Stall, 2010).

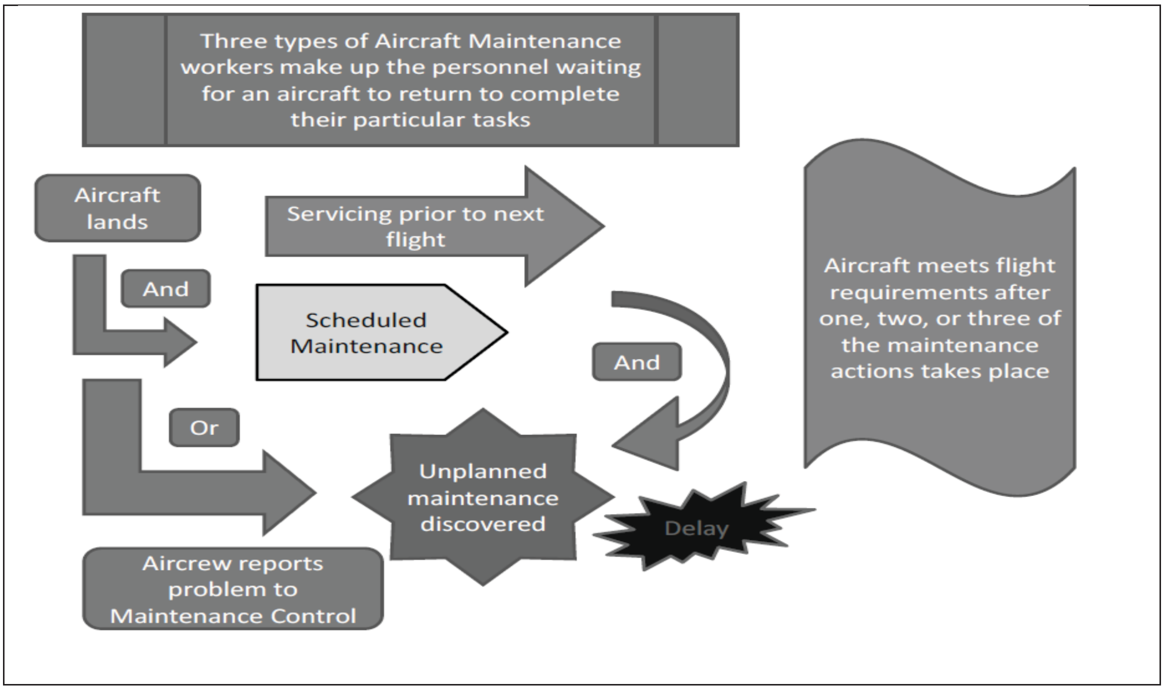
Another research study was made by Ayeni, Ball, & Baines (2016) was enough inductive with the purpose of extending lean adoption and verifying the suitability in MRO organization. The study included a industry wide survey which showed that the complexity in MRO industry was born from aviation regulations and the limitation of facilities, reduces the positive effects of lean principles which applied to MRO industry where there are too many different and independent services (Ayeni, Ball, & Baines, 2016).

Hölzel, Schröder, & Thomas Schilling (2012) proposed an optimization method for aircraft maintenance tasks in MRO and scheduling in an aircraft lifecycle simulation. They used Prognostics and Health Management to reduce the operational interruptions and maintenance downtimes for unscheduled and preventive maintenance. The goal of the study is to minimize aircraft maintenance downtime and costs for the change of aircraft scheduling and labor within the limited maintenance capacity. Alafres (1999) described an actual aircraft maintenance labor scheduling to reduce the cost. A new integer programming formulation has been presented in this paper. A report for determining maintenance power has been described by (Bell & Stucker, 1971). This study was not enough for finding a complete methodology because of limited data, but was quite good for the time reported, because several approaches had been illustrated for expanding the basic methodology. Muchiri, (2002) carried out a research project to develop a cost-effective maintenance planning. This study is well organized and has full of maintenance definition. The planning and execution of maintenance task were classified as line maintenance and base maintenance which had been deeply investigated and analyzed.

According to database of Council of Higher Education of Republic of Turkey between the years 2000 and 2014, the number of thesis about Airline is 242. 11 percent of this thesis have industrial engineering subject and 50 percent of these has been studied for airline fleet and crew scheduling, and 25 percent of airline revenue management. In addition, there are 185 theses about Aviation and a few of them (8 percent) is related to industrial engineering field. Only one dissertation has been found in the database which is made by Yılmaz, (1998). The study defines the needs of approved maintenance organization, aviation quality standards. A typical line maintenance model and organization chart in an MRO organization can be respectively seen in figure 2.1 and figure 2.2.

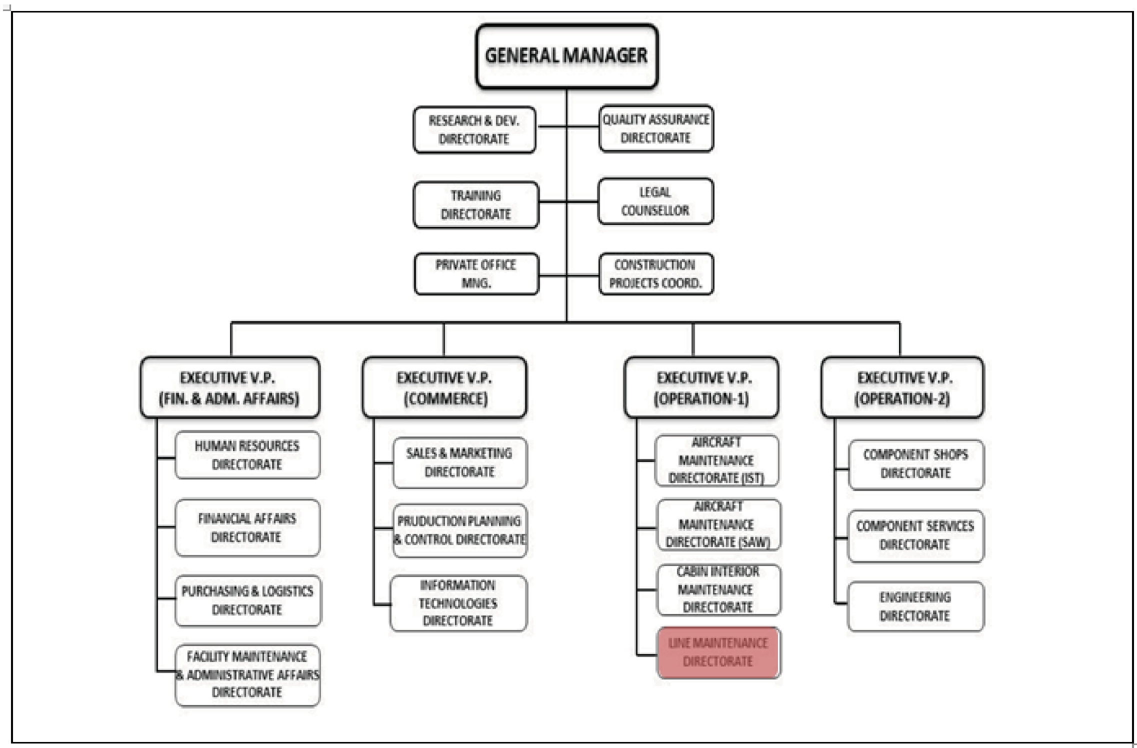
During the literature review many articles and book have been reviewed, but none of them was explanatory and supported with real VSM methods and lean implementation for the specific area in MRO industry such as line maintenance through the lean history which is also seen Appendix 1.

Figure 2.1: Line Maintenance Model



Reference: Aviation Maintenance Management, by H. A. Kinnison, 2004. New York: McGraw-Hill.

Figure 2.2: An MRO Organization Chart



3. METHODOLOGY

3.1 RESEARCH METHODOLOGY

In the research, elaboration and concepts of Value Stream Mapping theory are generated from data collection. The quantitative research method has been used as a data gathering instrument in terms of time and man hour. The research has been made thoroughly into the line maintenance area where the people have been investigated from the perspectives of each specific job they conduct. In order to collect numerical data and analyze the each process, the researcher used tools, such as questionnaires or databases. The specific information about the values, opinions, and behaviors has been culturally obtained by each participant in the study.

In addition, the ex-post facto design has been used as a method in which participants with qualities that already exist are compared on some dependent variable. Because the processes are not randomly assigned and they are also group based on a particular characteristic or specific features. In order to show the possible effects of an experience or process, simple ex post facto design may show a difference between the process for the actual and future states. The methodological choices have been made in this study are respectively, positivism from scientific perspective, deductive about scientific approaches, and quantitative research method.

The scope of this study focused on the principles such as specifying value and identification of the value stream. These two principles are major part of the lean thinking philosophy. The practice in this study was very useful to implement the data collection techniques and value stream mapping techniques which are helpful to identify every specification of process in the organization. The framework generated by the value stream mapping was used to gather data, to analyze the both techniques and measure the other sources.

3.2 SAMPLING AND POWER ANALYSIS

It is aimed to research the positive effects of VSM method in Aviation MRO environment, especially for the line maintenance which has very complex and independent process. The quantitative study is helpful for investigating the each process deeply for identifying waste and understanding the value in service improvement by comparing and measuring all the data collected through this study.

The sample used in this research study was consisting of the specifically selected employees of the line maintenance in MRO industry. To create an effective and accurate value stream maps, the study required approximately 128 processes which identified by the participants have been used to specify a set of items to measure the time and man hour. Every participant in the population has been selected with the same probability; therefore all samples were given the same weight. And no participant was selected more than one in the same sample. Participants in the study were consisting of managers, engineers and technicians.

They are responsible to perform all tasks of line maintenance and they are also asked demographic question for the purpose of understanding the variations in maintenance experience.

A priori power analysis was made to determine the appropriate sample size in order to ensure the validity and strength of the study. The analysis was performed using the statistical calculating tool G*Power 3.0.10. The results from the calculations showed that the sample size is 128. The value was calculated with the following parameters: effect size of .25, power (beta) of .80, and alpha level of significance 0.05.

3.3 INDEPENDENT AND DEPENDENT VARIABLES

The cause and effect relationships were investigated in the research study for finding the possible effects, the actual situation and future situations after applying VSM methodology were defined as independent variables. There are two levels to this variable, namely the current and future state. The scale of measurement for the independent variable is nominal. And the dependent variable was a process which potentially influenced by VSM methodology.

3.4 RESEARCH QUESTION AND HYPOTHESIS

How appropriate VSM approach is for line maintenance improvement in MRO industry? And what are the most important factors to implement a VSM method for the line maintenance operation?

Second, it is necessary to demonstrate how can VSM be adjusted for the unscheduled and scheduled maintenance services in line maintenance or MRO industry?

Null Hypothesis (H_0); there will be no significant difference between actual situation and future situation after using VSM method in line maintenance process. It means that there will be no valuable improvement.

Alternative Hypothesis (H_A); there will be significant difference between actual situation and future situation after using VSM method in line maintenance process. It means that there will be no valuable improvement.

3.5 INFERENTIAL STATISTICS

In order to observe an improvement, an experimental study has been implemented. Process characterization and optimization, evaluation of material properties, service design and development have been observed with the comparative experiment such as VSM workshop. In order to test the variables, T-Test statistical method has been used. T-Test provides an objective framework for the comparative experiments and could be used to test the relevant hypotheses. Because of having two comparative samples whose variances are unknown and independent samples, two tailed T-test has been performed with $\alpha=0.05$.

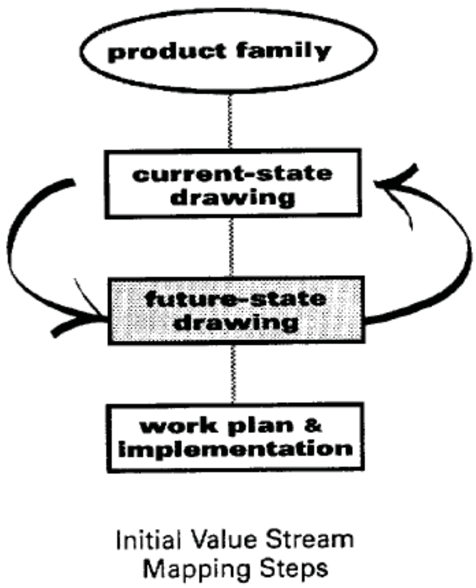
3.6 THEORITICAL FRAMEWORK

Lean thinking tools such as Value Stream Mapping has been generally used for manufacturing environment. However, line maintenance as a service organization has full of services and is different from the manufacturing process. Even though they have similarities for both service and manufacturing process, there are huge differences such as location, inventory, demands, operation and production (Linton, 2015). Therefore the same methods are valid for both service and manufacturing organization. Especially, VSM method might be advantageous to implement into service organization such as line maintenance.

Rother and Shook (1999) described the VSM as independent method which was used to identify the information flow across the all processes in a manufacturing organization.

They introduced and created a few steps to generate a value stream map. These steps can be seen in figure 3.1

Figure 3.1: Initial Value Stream Mapping Steps



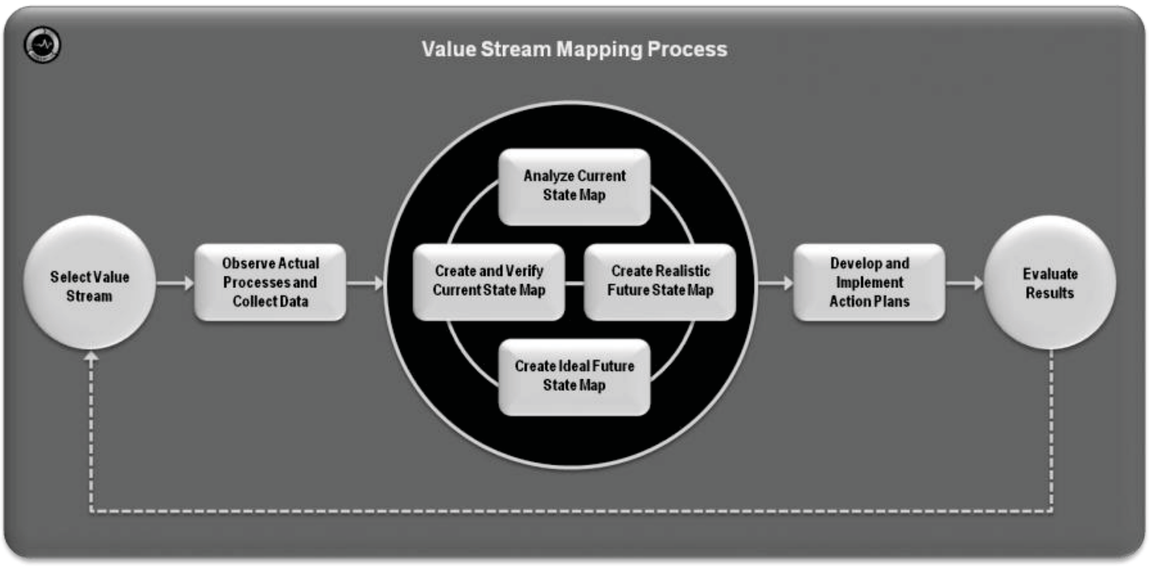
Reference: Adapted from the book (Learning to see: Value stream mapping to create value and eliminate muda, 1999)

VSM is not only a basic planning tool to identify wastes, to design the solution and communicate lean concepts, but also it has real benefits such as highlighted dependencies, opportunities for the application specific strategies, improved understanding of complex systems, synchronized and prioritized continuous improvement activities (Dailey, 2003).

The organization of value stream maps consist of two states; current and future states. The current-state map illustrates the performance of present service processes, whereas the future-state map stands for an ideal status of processes and a goal for improvement actions (Sullivan, McDonald, & VanAken, 2002). Besides, a current-state map is used to define the sources of waste and instruct the participants to select the identified wastes. At the end of VSM, by comparing of the two maps, the improvement plan is generated. This improvement plan is considered a guideline to minimize the waste and observe the improvement of production or services processes which are change from current-state to proposed future-state (Chen K. M., 2011).

In order to conduct a real VSM workshop, it is necessary to have enough knowledge through the participants of workshop. The knowledge and experience has to be shared between the participants who are needed to lead by a lean facilitator or supervisor. On the contrary, the workshop will be not effective without any supervisor who can also manage and make the necessary arrangement and the observations. In order to perform VSM, there are generally acceptable four steps in the lean literature. Therefore, these steps could be firstly used as a guide to perform a standard VSM in the organization, even though the scope of work is almost different from the standard processes which are like in manufacturing and product development. These four steps guide to participants a way to build an effective VSM workshop within the lean principles which is also seen in figure 3.1. First step is determination of all process in the organization by the help of each individual. Second step is mapping the actual situation of organization. Third step is also mapping and it demonstrates the progress after finding improvements and eliminating the wastes. The fourth step is the final stage where the VSM workshop is analyzed. In this step some discussion are made about how the improvements could be implemented. Before starting to apply initial VSM steps, it is firstly necessary to see the overall process schematic which is seen in Figure 3.1.

Figure 3.2: Initial Value Stream Mapping Steps



Reference: Bojic, Z. (2015). systemico.ca. www.systemico.ca:

Define each process in the organization;

Line maintenance includes various service processes which also include hundreds of tasks which are scheduled, unscheduled or on demand. Some of them are similar, some of them not. In order to avoid confusion between different processes and routes, it is necessary to define certain value stream. In the aircraft maintenance, especially in line maintenance organization the selection of the service family refers to the choice of the line maintenance service that has complex design. A few of them is the same or similar and the method of maintaining the services is not identical. The selection of a specific service family begins with when an organization first starts to create value stream maps. Before starting to create state maps, it might be useful to see the guideline in table 3.1.

Table 3.1: Guideline for CSM and FSM

Step	CSM Guideline
1	*<optional> Create or obtain a "Zeroth" map to start the visualization*
2	Define and follow the work being done by the process
3	Define tasks that make up the process
4	Arrange the tasks and define the information flows between them
5	Collect and interpret process data
6	Apply selected process data to the map
7	Assess value (or lack thereof) of the tasks and the info-flows between them
8	Apply relevant value judgments to the map
9	*<optional> Use a Dynamic State Mapping to better understand information flows and iterations*
	FSM Guideline
1	Working to a takt time
2	Visible and explicit information flows
3	Balance the Line
4	Apply relevant value judgments to the map
5	Streamlined analysis and review processes
6	Minimized formatting
7	Markers for detailed improvements

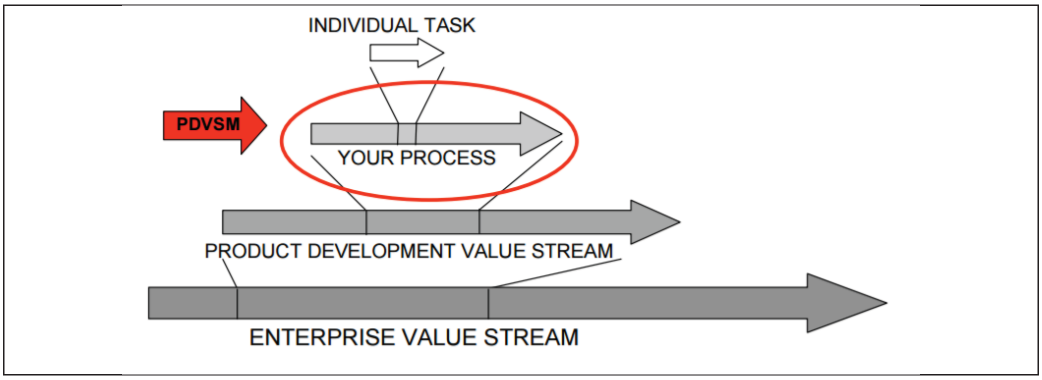
Reference: Adapted from the manual prepared by Dr. Hugh L. McManus (2005)

Create a Current State Map (CSM)

The current-state map has been drawn by the following process;

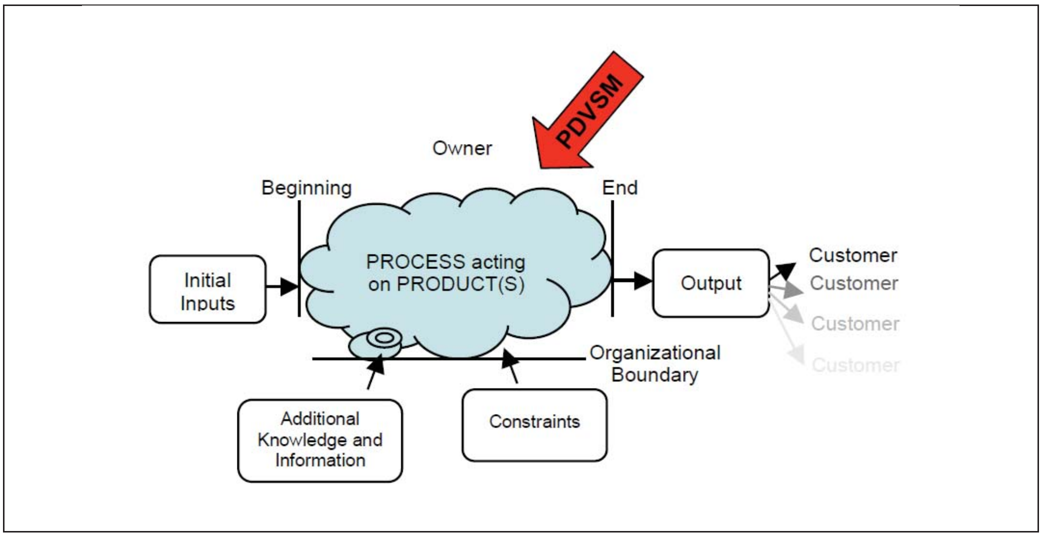
Step 1: After determination of each process, they should be mapped into a very big paper with the all detail such as time and distance. The information is to be gathered from interviews and experience with each person responsible for every major action along the value stream. If the team responsible for each individual task or action along the value stream is small enough to bring them into a room and use large post-it notes to draw up the high-level process map. It might be helpful to see figure 3.3 and figure 3.4 in order to make useful process definition and the boundary of the problem in the process.

Figure 3.3: Application to definable process.



Reference: Adapted from the manual prepared by Dr. Hugh L. McManus (2005)

Figure 3.4: Bounding the problem



Reference: Adapted from the manual prepared by Dr. Hugh L. McManus (2005)

Step 2: Once the high-level process map is completed it should be passed along to each of the team for review and revisions. When all participants accept the basic structure of the current-state value stream map, step 2 is finished.

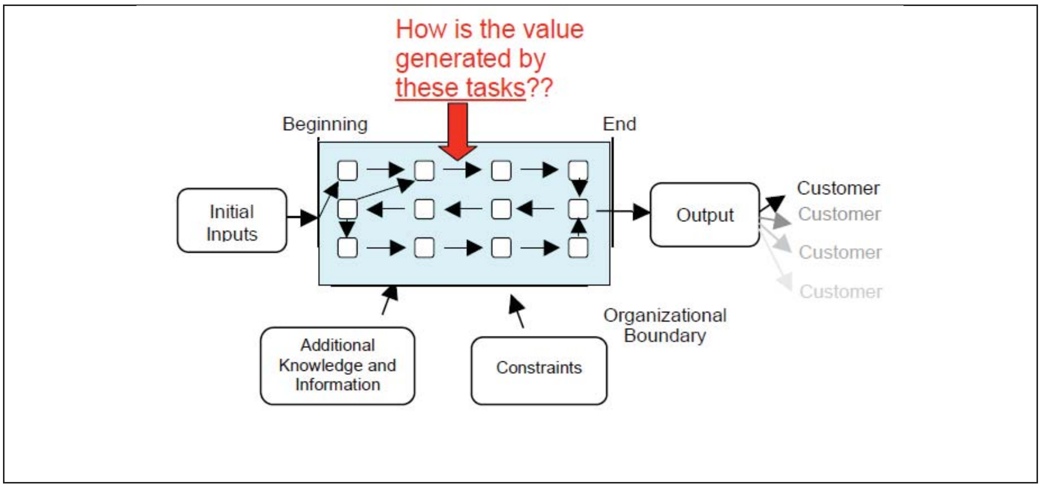
Step 3: The high-level process map is retouched after step 2 to predetermine level of specificity. Sub-process maps of each high-level action have been created to demonstrate and to identify each action along the value stream.

Step 4: For each action in the process maps, every task has to be questioned based on its type, time, location, equipment used, and root cause.

Step 5: Cycle times are added to every action on the emerging value stream map. These must be actual measured times, not just the ideal or best time recorded to complete each action.

Step 6: The team now determines if each action on the value stream map provides value to the customer or if it is a form of waste. Value creation process is seen in Figure 3.5

Figure 3.5: Value creation process



Reference: Adapted from the manual prepared by Dr. Hugh L. McManus (2005)

Draw a Future State Map (FSM)

After finding improvements and eliminating the wastes from CSM, another map is drawn again to analyze the data collected in CSM and removing from it as much of the waste as possible. It is outlined in the following steps:

Step 1: The value stream manager draws a modified value stream map of the future-state by removing as many of the actions classified as waste entirely from the system and rearranging the sequence and methods of production in order to allow for smoother flow of the instructional product.

Step 2: Give the future-state map of the value stream to the team for their review. Based on their feedback the value stream manager makes changes to the map.

Step 3: Have the entire team sign-off on the future-state map as acceptable.

The method for mapping value that is defined here is meant for producers of instructional products. This value stream mapping method will provide a detailed road map on how to map the value stream accomplishing all five of the steps identified by Rother & Shook (1999).This study focused on the first four steps of value stream mapping to meet its three objectives:

- **a.** To determine how a value stream mapping method based on those used in line maintenance can be improved for capacity increase.
- **b.** To determine what service activities provide value to an organization with these FSM.
- **c.** To provide a foundation for organizations to standardize their instructional production processes so that rigorous methods of continuous improvement can be implemented.

Analyze and plan the improvements in VSM;

At the end of the VSM workshop, all improvements data has to be collected to analyze and develop. In order to develop improvement ideas, a few aspects of value in product development can be seen in Appendix 3. Final discussion is made for the future forecast by enhancing the vision of organization from the lean perspective.

4. DISCUSSION

4.1 RESEARCH TOOL

The primary research tool in this study is a VSM Workshop with the participants from each department related to line maintenance.

The first objective was to create a current state VSM for the whole process of line maintenance operations. In order to show all activities in one VSM, activities have been initially grouped into three categories such as schedule line maintenance, unscheduled line maintenance and support line maintenance. Also, the VSM members have been categorized according to this categorization. Every specific member defined the action taken in the process and every action has been demonstrated in CSM, and all the processes were separately listed into three different categories. For FSM, various improvement ideas have been created and many wastes have been eliminated to make more simplified map with the lean thinking perspective. In order to share and demonstrate CSM and FSM, the Visio program has been used with the standard VSM icons. (See Appendix 14)

VSM workshop has been carried out in groups of 10-15 people with lean experience. Besides, a lean team supervisor helped the team to understand the philosophy and challenged them to evaluate the actions taken by each individual. The workshop has been conducted for 3 days; First day for CSM, second day for FSM, and the last day for analysis, discussion and planning. The group consists of the actual people working in the processes. VSM workshop has been conducted with 30 participants who are the experienced employee of the MRO. Each of them represents the related part of the process. Because of having too many process and the categorization, the participants have also divided into three group who could be easily identify the own process in the organization. Besides, it provides a depth view point for identifying the process more detailed. Every action in the process has been analyzed deeply to improve more ideas. Before starting to VSM, the data collection sheet is very useful to gather all necessary information in one hand. (See Appendix 4 and Appendix 5)

Day 1 - CSM

At the beginning of the workshop, the participants described their responsibilities and experiences about line maintenance. The VSM introduction is held by the lean supervisor. The participants had a little knowledge about the lean thinking and its powerful tool VSM. Right after the introduction of VSM, the charter document was prepared to keep the records. Charter document includes the definition of workshop, the scope of work, limitation and constraints, current state, expected deliverables, boundaries, customer standards, the names of the team leader and other members, tool gates, milestone periods, and date and duration. After workshop this document has to be signed by each members of the workshop with the leadership approval. Because of the size and variation of the services in line maintenance operation, it is necessary to divide the process in three different categories such as schedule line maintenance, unscheduled line maintenance and support line maintenance. Groups were shared according to these categories by based on the individuals' responsibility. Schedule line maintenance mainly consist of planned actions which are A check, ramp check, transit check, weekly check, defect rectification, servicing, technician assignment, operational meeting so on. Unscheduled line maintenance consists of on condition process such as ETOPS management, tire and brake unit replacement due to hard landing, non-routine defect rectification, troubleshooting and so on. For these categories, the processes were determined and measured, and the completion time of every process was calculated. (See Appendix 6 and Appendix 7)
After listing the all process in the categories, tree horizontal lines have been drawn on the map to demonstrate which process belongs to which categories. Then every action in the process has been written on the post-it which has different colors to determine the each responsible department in the organization. But not all of them symbolized the departments; pink and green were respectively used for demonstrating the waste and value adding activities. Some activities or processes, which have the relationship between each other, were linked with arrow connector. The direction of the arrow was determined according to the direction of the process flow. The CSM of the workshop can be seen in Appendix 11.

However, at this stage the discussions about the problem solution have to be postpone the end of the work shop since it is important to discover all process at one point. It is aimed to focus on current state. Some important line maintenance process can be seen in Appendix 8, 9 and 10.

After finishing the last process of all which were found at the beginning, the completion time of schedule line maintenance were calculated. The lean measurement can be used for calculation (See Appendix 2). The same was made for other two categories and finally CSM come insight.

Day 2 - Future state

In order to avoid the confusion, the current state map has been recorded and the most important activities are copied to the future state map. All wastes were eliminated, so there was no space in this map for them. The discussion about improvement was quite sufficient, but still it is necessary to have more time and more lean training to enhance the vision of participants. However, it was enough, because most workers create ideas while they are working, they always look for a shortcut. Most of them had already an idea to improve their work process.

The group had a number of improvement suggestions which are also noted by lean supervisor. The future state has been completed in the light of these ideas. Every suggestion was evaluated with the help of lean principles. All non-value adding actions had returned to improvement ideas were organized and sorted from low to high according to their benefits and efforts, in order to decide easily which improvement ideas could be first implemented as a project in the organization. Because of every different color symbolize the each department; it is to see the responsibility ranking of departments in the map for the improvement suggestions and possible implementation. The FSM of the workshop can be seen in Appendix 12.

Day 3 – Analysis

After the workshop, the maps were transferred to computer environment via Microsoft Visio in order to spread knowledge and analyze the workflow.

In brief, workshop was really effective. Hence, it was the first VSM trial in line maintenance. It was hard to focus on the scope of work which is various and independent.

The main requirement was to have a process with a need for improvement and it was supplied and shared by participants working in the process. Therefore, it will be easier to implement the ideas created in this workshop. The expected result of VSM was attained at the first glance; creating a shared vision, reducing lead time, improving specific processes.

However, the improvements need to be implemented to see the real effect and success. Therefore, the responsibility of the participants will continue until the last improvement is applied.

All participants shall be in communication with the feedbacks of implementation efforts. In order to be successful, the participants and their colleagues should have kept motivated for further improvement efforts.

Participants

There are three main groups which are parts of scheduled line maintenance, unscheduled line maintenance and support line maintenance, and nine subgroups which are the expert of the process under the three categories of line maintenance.

Total population consists of twenty seven participants who are managers, chiefs, supervisors, engineers, and technicians who are working in the process and working before and after the process.

The number of groups could be increased but it leads to spent more time and more man hour. The processes in line maintenance organization are too big to fit into one map. VSM could be replicated for all individual process such as the long process like A check, and complex process like defect rectification.

4.2 ANALYSIS

The completion time of process has been observed by comparing CSM and FSM. It is very simple mathematics to calculate the proportion of the change in the completion time of process. According to the result of VSM Workshop, the improvement progress with the VSM method will be nearly 11 percent for the process of schedule line maintenance, 1 percent for the process of unscheduled line maintenance. It has been not observed any change in the process of support line maintenance. Hence, it is really hard to see the support demand arisen from other departments.

In order to assess statistically the difference of the process both in current state and future state, T-Test has been performed. (See Table 4.1) The dependent variables are the processes defined and calculated in the VSM Workshop. Because of having two comparative samples whose variances are unknown and independent samples, two tailed T-Test has been performed. Because of I don't have information about direction of possible difference, I preferred two tailed t test with $\alpha=0.05$.

Table 4.1: The Test Result

T-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean(M)	102,8333333	97,33333333
Variance(SD)	14637,66854	12166,40449
Observations	90	90
Hypothesized Mean Difference	0	
df	176	
t Stat	0,318701089	
P(T<=t) one-tail	0,375165542	
t Critical one-tail	1,653557435	
P(T<=t) two-tail	0,750331084	
t Critical two-tail	1,973534388	
"p<0.05"		

Even though the result of VSM may be seen as effective, the result of T-Test disaffirms it. According to results, CMS (M=102.83, SD=14637.66) the score, CMS Score is not significantly different from FMS (M=97.33, SD=12166.40) scores. Because of the results are significantly difference, $t(176) = 0.318$, $p>0.05$, the null hypothesis has been not rejected.

Therefore, the results and findings should be discussed both theoretical and practical perspectives. In order to have better understanding how these concepts relate to service improvement in MRO environment or how could be applied into maintenance services, it is essential to create a lean strategy for line maintenance services which have very complex process contrary to manufacturing and product development. The findings and results after performing T-Test also show the result of VSM is not expected as offered in the lean manufacturing or in lean product development.

Line maintenance comprises various services in both hangar and apron side in the airport environment. The problem is to maintain every service and process in a complex and restricted environment. Aviation has own strict rules for safety and quality. In order to keep the aircraft airworthy is another challenge. By the nature of the aviation, scheduling is changing in every minute. Because of busy aircraft scheduling, uncertainty does not let to make future plans. Hence, there are too many special problems such as high variability, limited work scope and material requirements, unpredictable response times from support, quick operations in a short time, difficulties in managing shared resources, and physical restrictions on movement of maintenance. These all cause complex and unpredictable flow paths which is very different from the flow of lean manufacturing. Besides, the size and type of aircraft fleet bring another complex problem and limitations such as certification, various types of servicing, specific skills for each type of aircrafts and so on. Therefore, for performing only VSM seems impossible to adapt the lean enterprise model to the MRO environment, especially for the line maintenance. In the literature, there are lots of lean applications adopted by several MRO companies which had limitedly used to improve their processes for only their heavy maintenance, component repair and engine overhauls. All these process have one piece flow and they are scheduled and perfectly suited to implement all lean principles. VSM is taught easily when using a one piece flow, having scheduled work, scheduled plan and scheduled interval for each process. However, adopting a common language of VSM method to the complex world of line maintenance operation is a different story. For example; in order to adapt the mixed model value stream to product development, the useful guideline introduced by Rother and Shook (1999).

This guideline for lean product development is an upgrade version of lean manufacturing steps which is previously mentioned. The new guideline has twelve steps instead of four and it might also be analyzed to compare the line maintenance services with product development. In fact this guideline seems as an expansion of previous four steps. The biggest difference in the guideline is using first in first out method instead of one piece flow, and it has a backup solution in case of the flow changes are happened. The other difference is scheduling the time interval with pacemakers. The main suggestion in the guide is making more than one VSM for each process.

This guideline was helpful to make some little arrangements to combine the steps into VSM for line maintenance service which is more complex and has much uncertainty.

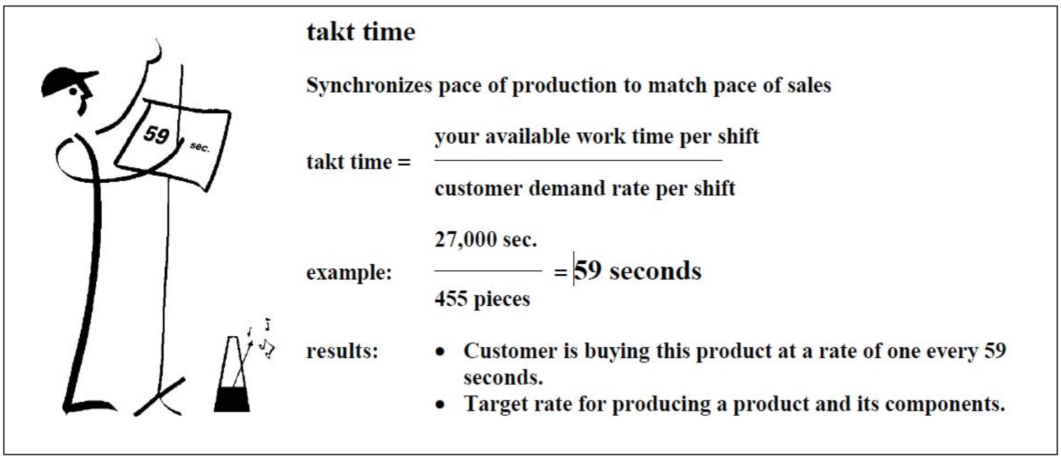
Normally, it could be very hard to use this guideline for simple product development and if it is taught that it could be much harder to use for line maintenance operation which has the complexity and uncertainty, it seems nearly impossible.

In this study, VSM method has been tried to develop for improving the line maintenance capacity.

The guideline has been utilized like below;

a. **Product families:** Instead of product families, the term of service families has been used to describe the process. The service list was created at the beginning of the VSM.
   To add a work definition for each process was helpful to follow up the process flow.
b. **Takt time:** The demand is always fluctuating in line maintenance operation, so the level of capacity and capability of line maintenance department has been determined to meet changing the demand. However, takt time is not exactly measured. In the workshop, it only depends on the participant's experience. It is seen in Figure 4.1.

Figure 4.1: Takt Time Calculation



Reference: Adapted from the book "Learning to see", by (Rother & Shook, 1999)

c. **Finished Goods Strategy:** This is not applicable for line maintenance service. There might need to be strategy for removed component and spare parts to accelerate the return process. In the work shop there was a non-value adding but necessary action about component return to repair shop. Bu the process and concept different from the finished good strategy.

d. **One piece flow:** Between the time of arrival and departure, the process does not follow the one piece flow. There are many paths to take scheduled, unscheduled and on demand actions to make the aircraft airworthy. However, in this workshop the actions were divided into three categories and the tree parallel flows were drawn in both current and future state map.

e. **Fist in First Out (FIFO):** This philosophy seems unusual for service environment, especially for line maintenance. Because of having too many complex process and independent processes which have different completion time and not having a one piece flow, then the standard method could not be applicable.

f. **Pull systems:** It is one of the most important part of Lean principle and also crucial for line maintenance operation. There should be perfect pull system to manage inventory and flow. But, it is still quite hard to implement the line maintenance area. Because, the demand of materials is fluctuating and is requested on demand. The condition and requirements is seen as emergency in line maintenance operation. The priority is always given the aircraft which is the nearest to departure. Time limits the flexibility and obstructs to implement a valuable pull system as defined in lean manufacturing.

g. **Equipment to support takt time:** Takt capability can be established for line maintenance. Completion time for each process which is required equipment in the service family could be forecasted. As a general target in the work shop, the equipment was loaded to about 90 percent to allow for the variation of service demand within the service family. But, it can increase the service capacity and the cost of investment.

h. **Ground Time:** It is a time when an aircraft is available to maintain on ground. This is based on aircraft scheduling and fleet operations. Lead time depends on the condition of the defects for unscheduled process. It is hard to establish the lead time for the equipment in the unscheduled process with the VSM Method. In order to calculate the real lead time, it is necessary to analyze backtrack database of all unscheduled process and VSM is not enough to scan the historical database, it is only capable to define the process and to measure the individual's experience.

i. **Scheduling a point:** Normally, It is very easy to determine a point where flow ends and to schedule it for one piece flow. Certain MRO operations have standard or developed scheduling tools. However, scheduling for line maintenance could be made only for certain tasks in certain ground time which is not always certain in airline operation. In the workshop estimated numbers have been used to identify the certainty for scheduled process. It is the major challenge in line maintenance operation. Especially, for the airline which has more than three hundred aircrafts with flying more than two hundred destination points, it is the biggest issue and it is quite difficult to solve with VSM. In the study it has been tried to use a few pacemakers to support the schedule.

j. **Pitch or management time frame:** Pitch is a representation of takt image. It is generally used to pace and monitor value stream performance. The principle of the calculation of pitch is to early identify and timely reaction to defects. This was very useful to track and plan. The key purpose is to decrease the pitch time which could be matched to the organization's capability to react the problems. In the study pitch time varied from low to high because of fluctuating demand. The terms and concept is not well applicable and suited for line maintenance operation. But it was useful to make a time frame with the takt time of every action.

k. **Alternative modes:** This is really good idea to find alternative modes for the complex line maintenance environment. In order to apply this rule, it is necessary to replicate more and more VSM for each process.

In the study, three value streams were described in parallel in one map. In the work shop the trends in the service demand were exceed the standard expectation of lean manufacturing. Therefore, additional value stream mode has been developed to control every service in detail

The result of conducting a VSM workshop in line maintenance organization is useful but it is not very effective when considered the time and labor spent. Eventhough all the rules above from the guideline written by Rother & Shook (1999) could be fully applied to MRO operations, they should be developed and redesigned for line maintenance. The operations in the hangar or apron, support functions should be all synchronized. There should be a monitoring system which should be capable of alerting the related parts of organization when the flow has broken down.

VSM is not enough to increase the capacity of line maintenance service and not adequate to conduct with the paper and pencil in the light of the experience of participants. It is also necessary to develop a computer based VSM application which can automatically calculate and measure the identified data and it should have a database which can communicate with the database of the organization. Hence, the experience and one experimental study are not enough to improve such a big and complex operation.

Even if it is applicable, VSM application should be replicated in many instances to analyses the real framework of line maintenance.

There are many MRO operations implementing and using these techniques. Many improvements have been done for many years in MRO operations by using the real power of lean. However, there isn't any VSM study for line maintenance has been found in the literature. The improvements resulted from VSM make processes look better, get people excited, improve the work flow, and get results in the areas where the operation is scheduled and has one piece flow. If there is a complexity on the contrary of standard case, the result of VSM which is implemented with traditional methods is not enough to see significant effects on improvement. In order to overcome these difficulties in service development, it is necessary to modify the VSM method. In the literature there are some examples which are previously mentioned at this paper, they change the definition with the new one for demonstrating the difference. In order to create a new guideline for line maintenance services, first it is necessary to draw the borders. It means capability of an MRO organization. The constraints and limitations of line maintenance operation have to be determined and the all processes have to be purified. By doing these determination and simplification, it could be helpful to develop a new method for complex processes like the services of line maintenance.

In this study the quantitative approach has been used to verify which of hypotheses are true. In the lean theory, developing VSM methods were used for measurement.

Experimental control and manipulation of variables have been observed at the end of the work shop where the empirical data had been collected. The advantage and disadvantage of using value stream mapping approach was supported by the work shop. General lean principles and steps have been used for implementing VSM. The method developed in this study uses standard VSM symbols which allows more accurate mapping.

The VSM application for line maintenance operation might be seen as effective, if the experimental data could be increase and a computer based application could be developed.

VSM application for service development in line maintenance operation needs to be proved from scientific perspective to future research.

5. CONCLUSION

Firstly, the null hypothesis cannot be rejected based on the T-Test which was performed with the empirical data resulted from VSM workshop;

Null Hypothesis (H_0); *there will be no significant difference between actual situation and future situation after using VSM method in line maintenance process.*

It means that there is no valuable effect of VSM in line maintenance within the complexity and uncertainty. If this VSM is enhanced with the higher number of participants and is separately made for each process, then it could create significant impact on the line maintenance improvement.

Secondly, the research questions of this study are fielding like below;
How appropriate VSM approach is for line maintenance improvement in MRO industry? And what are the most important factors to implement a VSM method for the line maintenance operation?
In this study, in order to gain empirical data, a VSM workshop has been conducted with the standard VSM procedures such as the procedures of manufacturing and product development in the literature. While adapting the VSM to line maintenance operation, some considerations have been observed. The complexity and limitations in the line maintenance makes difficult to find improvement opportunities. By contrast with the general process in manufacturing and production, the processes in the line maintenance operation are independent and not in order and one piece flow.
Because of these reasons, it is very hard to implement a standard VSM without any modification for line maintenance.
Another considerable point is to choose the suitable scope for VSM.
In order to describe whole scope, it is necessary to have participants from each department to define each work process with details. Besides, the empirical data and information collected at the end of the VSM workshop from these participants are not certain. It only depends on individuals' experience which is the main source of information. This uncertainty could be reduced with the sufficient increase of the number of participants. However, it is nearly impossible to apply in practice. Increasing

the number of participants in this complex process only makes sense, if the number of VSM is replicated for each process of line maintenance. In the workshop ninety process were identified with the thirty participants.

How can the value stream mapping be adjusted for the unscheduled and scheduled maintenance services in line maintenance or MRO industry?

In the workshop, in order to fit both scheduled and unscheduled process to one map, two flows have been horizontally drawn to demonstrate the process separately. It was aimed to control the VSM with the all actions in one place. In the workshop, improving unscheduled process was the most challenging part, so that it has not been observed any improvement in unscheduled process after the implementation of VSM. On the contrary, 11 percent of improvement has been observed for the process of schedule line maintenance.

The goal of this study was to expand the understanding of VSM Methods and to observe its effect on line maintenance operation. Eventhough there are many considerations and limitations in the utility of VSM for line maintenance operation, the result of the study was nearly satisfying and encouraging to develop a modified VSM method for the future research. If the necessary tool is developed such as computer based VSM application to collect the real data and to compare it with the database of the organization or a company in MRO, new avenues for future research could be created, both inside and outside the MRO industry. The study helps in understanding the effects of VSM methodology on the complex service area such as line maintenance operation. While this research does have its limitations and the uncertainty in the study area, it offers a resource which could be used as a basis for further scientific research.

The main target of the study is to implement a VSM to line maintenance operation for the process and demonstrate its real case application to find out the trueness of the hypothesis which is proved or disproved by the statistical tools such as T-Test.

According to the T-Test, the improvement suggested by the result of VSM workshop is not significant. Therefore, the null hypothesis has been not rejected.

However, the result of workshop seemed satisfactory with 11 percent of improvement in scheduled line maintenance.

If the current study; the VSM application could be replicated in high quantity with the large number of participants for every specific process; researchers would make more significant statements to improve the process.

Because of having limited time for the participants who are active worker of the organization and having uncertain information, the validity of VSM workshop could be questioned from the statistical perspective. It does not totally cover the real data which could be compared with the information comes from the knowledge and experience of participants in a limited time.

In addition to this, following the implementation is not impossible to track by human effort. Thus, it is necessary to develop a computer based VSM application which has capability of monitoring, tracking, alerting and collecting and comparing the information from the database of any organization.

For the future study, a computer based VSM application could be developed and the VSM methods could be updated.

REFERENCES

Books

Bicheno, J. (2008). *The Lean Toolbox: The Essential Guide to Lean Transformation.* Picsie Books.

Dailey, K. W. (2003). *Tle Lean Manufacturing Pocket Handbook.*

James P.Womack, D. T. (2003). *Lean Thinking.* Free Pres.

Liker, J. K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer* . New York: McGraw-Hill.

Monden, Y. (1998). *Toyota Production System: An Integrated Approach to Just-in-time.* London: Chapman & Hall.

Rother, M., & Shook, J. (1999). *Learning to see: Value stream mapping to create value and eliminate muda.* Lean Enterprise Institute.

Womack, J. P., T.Jones, D., & Roos, D. (1990). *The Machine That Changed the World* . New York: Macmillan Publishing Company.

Periodicals

Alafres, H. K. (1999). Aircraft maintenance workforce scheduling. *Journal of Quality in Maintenance*.

Ayeni, P., Ball, P., & Baines, T. (2016). Towards the strategic adoption of Lean in aviation Maintenance Repair and Overhaul (MRO) industry: An empirical study into the industry's Lean status. *Journal of Manufacturing Technology Management*.

Bell, C. F., & Stucker, J. P. (1971). *A Technique for Determinig Maintenance Mapower Requirements for Aircrafts Units.* California: The Rand Corporation.

Chen, K. M. (2011). The development of an nn-line RFID-based facility performance monitoring system.

Chen, L., & Shady. (2010). From value stream mapping toward a lean/sigma. *An industrial case study. "International Journal of*, An industrial case study. "International Journal of.

Doan, C. (2015). *2015-2025 Global MRO Market Forecast.* Oliver Wyman.

Hines, P. H. (2004). 'Learning to evolve: A review of. *International Journal of Operations & Production*.

Hölzel, N. B., Schröder, C., & Thomas Schilling, V. G. (2012). *A Maintenance Packaging and Scheduling Optimization Method for Future Aircraft.*

Kodali, R., & Jasti, N. V. (2014). *Lean production: literature review and trends*.

McManus, D. H. (2005). *Product Development Value Stream.* Massachusetts: Center for Technology, Policy, and Industrial Development.

Muchiri, A. K. (2002). *Maintenance Planning Optimisation for the Boeing 737 Next Generation*.

Nanova, G., Dimitrov, L., Neshkov, T., C.Apostolopoulos, & P.Savvopoulos. (2012). *Lean Manufacturing Approach in Aircraft MRO*.

P.Hines, Holweg, M., & Rich., N. (2004). Learning to Evolve: A Review of Contemporary Lean Thinking. *International Journal*.

Papadopoulou, T., & Özbayrak, M. (2005). Leanness: experiences from the journey to

Narender K. Ramarapu, Satish Mehra, Mark N. Frolick, (1995) "A comparative analysis and review of JIT "implementation" research", International Journal of Operations & Production Management, Vol. 15 Iss: 1, pp.38 - 49 date. *Journal of Manufacturing Technology Management*.

S.Tiwari, Dubey, R., & Tripathi, N. (2012). *The Journey of Lean*.

Smith, R., & Hawkings, B. (2004). *Lean Maintenance: Reduce Costs, Improve Quality, and Increase Market Share.*

Stall, S. (2010). *Making the business case for MRO.*

Stone, K. B. (2012). *A systematic literature review. "International Journal of Lean Six Sigma*.

Sullivan, W. G., McDonald, T. N., & VanAken, E. M. (2002). *Equipment replacement decisions and lean manufacturing.* Pergamon.

Thiruvengadam, A. (2004). *A Practical Method For Assesing Maintenance Factors Using VSM.*

Yılmaz, O. (1998). *Quality & JAR 145 Approved Maintenance Organisation in Aviation*.

Zhu, Z., & Meredith, P. H. (1995). *Defining Critical Elements in JIT Implementation*.

Other Resources

Bojic, Z. (2015). *systemico.ca.* www.systemico.ca: http://www.systemico.ca/wp-content/uploads/2015/04/VSM-Process-e1433078651392.png

Brinkman, K. (2015). *Luchtvaartfeiten.* Luchtvaartfeiten: ww.luchtvaartfeiten.nl adresinden alınmıştır

FAA. (1985). *FAR PART 1.* Seattle: FAA.

FAA. (2012). *Fderal Acquisition Regulatin.* FAA.

Linton, I. (2015). *Chron. smallbusiness.chron.com: http://smallbusiness.chron.com/five-differences-between-service-manufacturing-organizations-19073.html*

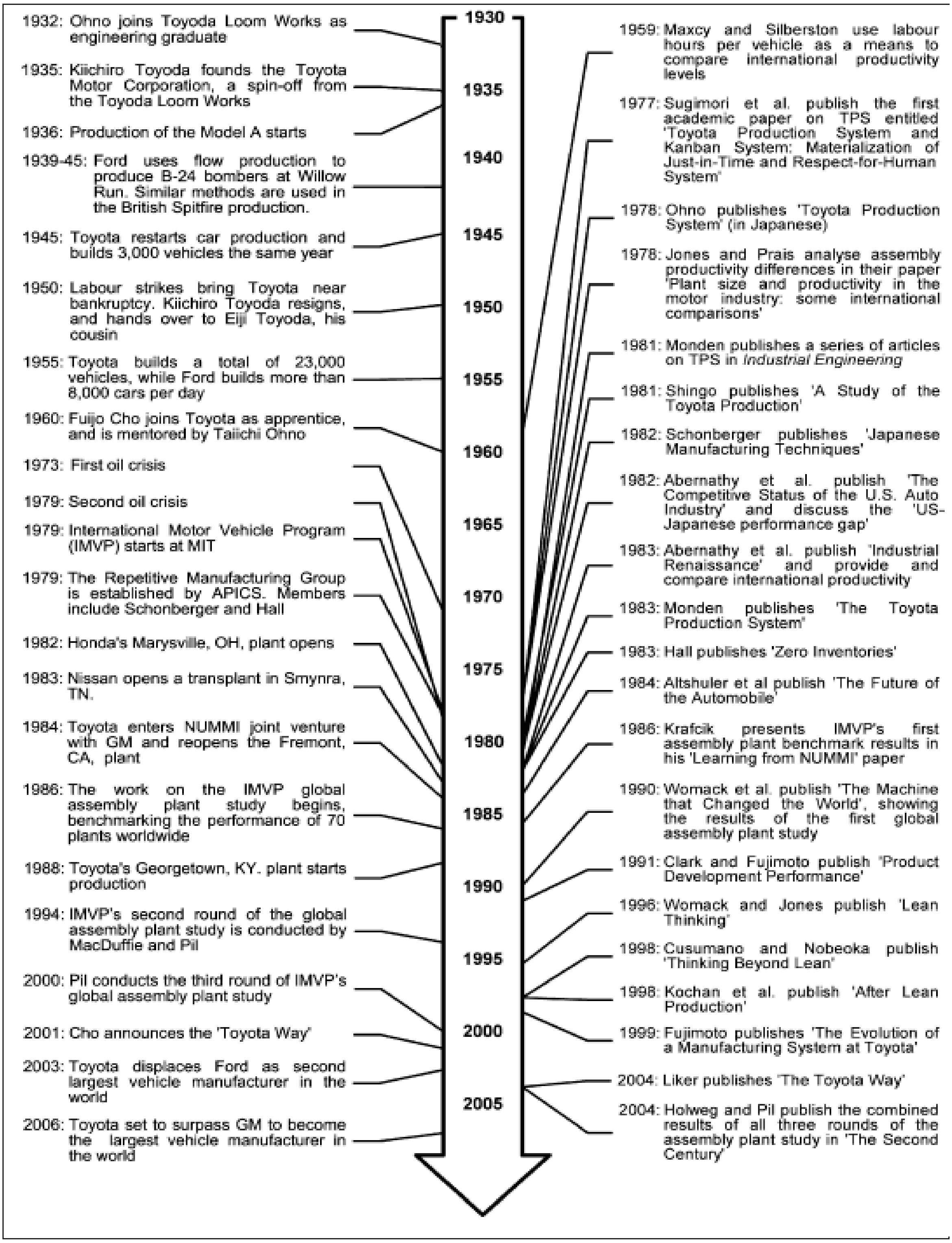
Williams, S. (2016). *aviationglossary: http://aviationglossary.com/*

York, K. (2016). *sustainametrics.com. 2013 sustainametrics.com: http://sustainametrics.com/index.php/page/display/lean_green*

APPENDIXES

APPENDIX.1: LEAN HISTORY

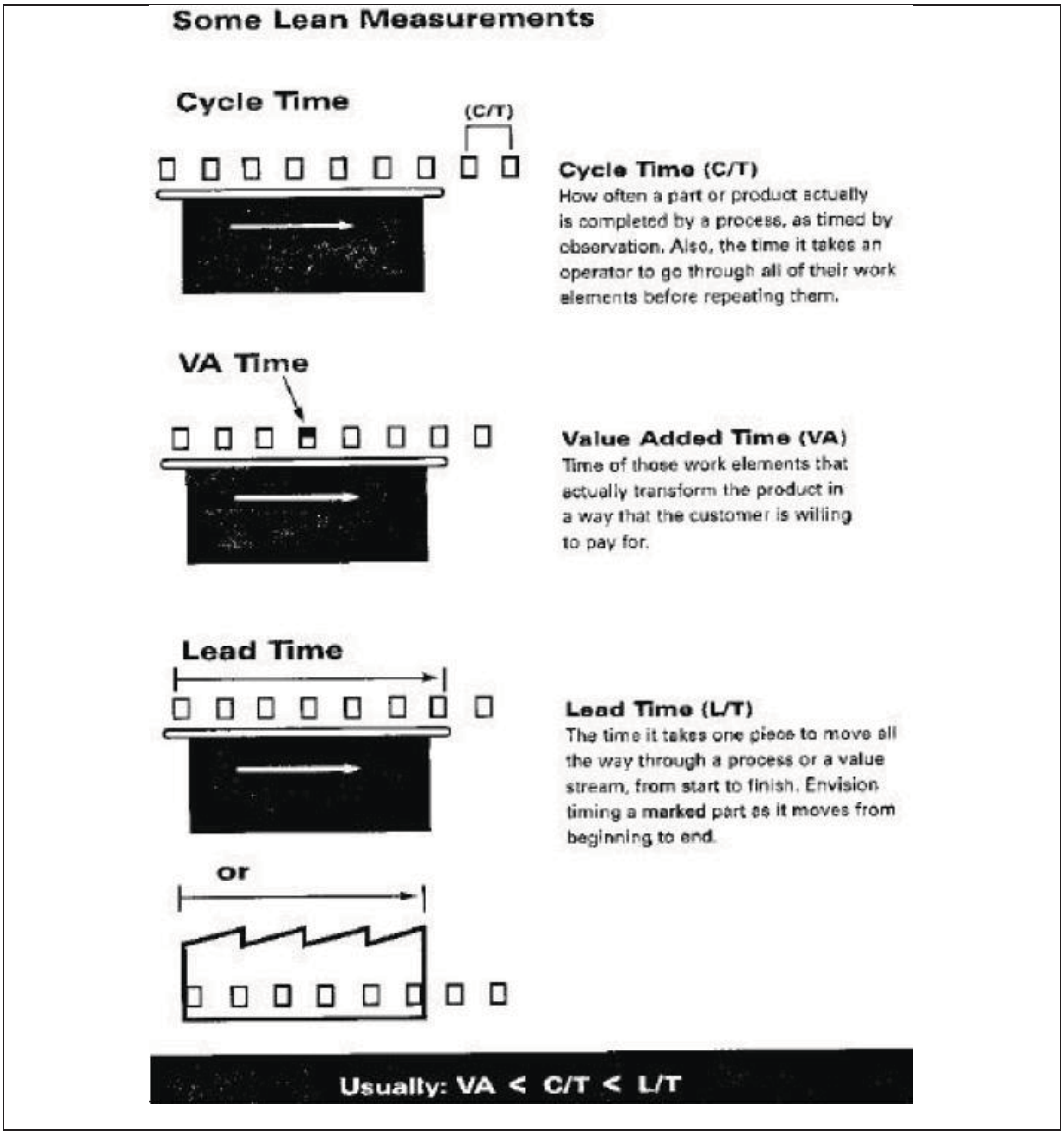
Figure 1.1: Lean History until 2005



Reference: (The Lean Toolbox: The Essential Guide to Lean Transformation, 2008).

APPENDIX 2: LEAN MEASUREMENT

Figure 2.1: Lean Measurement



Reference: Adapted from the book "Learning to see", by (Rother & Shook, 1999)

APPENDIX 3: ASPECTS OF VALUE IN PRODUCT DEVELOPMENT

Table 3.1: Aspects of Value in Product Development Tasks

Task Contributes to...
V1. Definition of End Product with desired Functional Performance
The task affects the definition and/or functionality of the end product delivered to the customer. It contributes directly to either the function or the form that affects the function. For example, requirements specification, design decisions, material/part/subsystem specification, geometry specification, etc.
V2. Definition of Processes to Deliver Product
The task directly affects the processes necessary to deliver the end product to the customer. It includes the design or procurement of the tools and processes necessary for manufacturing, testing, certification and/or other downstream processes, such as the creation of manufacturing and assembly procedures.
V3. Reduction of Risks and Uncertainties
The task contributes to eliminating uncertainties in performance, cost, and/or schedule. Typically, tasks include the analysis, prototyping, and testing of the product; the testing of tools/production processes, risk analysis, and cost/schedule management.
V4. Forming Final Output
The task directly contributes to the final documentation given to the customer or manufacturer. This typically includes the documentation of the materials, parts, subsystems, and systems, and documentation to meet legal and contractual constraints.
V5. Facilitating Communication
The task aids necessary communication. Typically includes reviews, meetings, and discussions with other company or industry personnel.
V6. Enabling Other Tasks
The task is necessary for other tasks to proceed, although it does not directly contribute to the design, production, or testing of the product
V7. Meeting or Reducing Cost and/or Schedule
The task emphasizes maintaining or improving cost and/or schedule, e.g., many management and process improvement tasks.
V8. Learning or Resource Improvement
The task contributes to the skill base necessary to do future work. This definition includes developing greater knowledge, improving tools or processes, creating new technologies, and communicating this knowledge throughout the team.
V9. Enhancing Employee Job Satisfaction
The task is a positive experience that increases the desire of the employee to do similar tasks; it enhances the professional development or skill base of the employee.
V10. Other
The task performs a necessary or valuable function not covered in the above categories. Examples may include contributions to work environment, environmental impact reduction, satisfying of regulatory or contractual requirements, the following of mandated processes, or the satisfaction other constraints.

Reference: Adapted from the manual prepared by Dr. Hugh L. McManus (2005)

APPENDIX 4: VSM DATA COLLECTION SHEET

Table 4.1: Data Collection Sheet Legend

Value Stream Analysis and Mapping Data Collection Sheet

General		**Resources**		
Activity Name		Elapsed Time		(days)
Location		In-process Time		(hrs)
Pers./Org. Performing		Core Task Work Time		(hrs)
Completion Criteria		Activity Based Cost		
Success Criteria		Special Resources Req.		
Other:		Chance of Rework/Time	%	(hrs)

Input #1		**Input #2**		**Input #3**	
Name		Name		Name	
Sender		Sender		Sender	
Transfer		Transfer		Transfer	
Quality	1 2 3 4 5 N/A	Quality	1 2 3 4 5 N/A	Quality	1 2 3 4 5 N/A
Utility	1 2 3 4 5 N/A	Utility	1 2 3 4 5 N/A	Utility	1 2 3 4 5 N/A
Format	1 2 3 4 5 N/A	Format	1 2 3 4 5 N/A	Format	1 2 3 4 5 N/A

Output #1		**Output #2**		**Output #3**	
Name		Name		Name	
Receiver		Receiver		Receiver	
Transfer		Transfer		Transfer	
Purpose		Purpose		Purpose	

Critical Drivers

(metrics/attributes)

Context (interaction with other VS)

Value

Non-Value-Added		Enabling		Value-Added
1- - - - - - - - - 2 - - - - - - - - - 3 - - - - - - - - - 4 - - - - - - - - - 5				

Functional Perform.	1 2 3 4 5 N/A	Enabling Activities	1 2 3 4 5 N/A
Defn. of Processes	1 2 3 4 5 N/A	Cost/Schedule Savings	1 2 3 4 5 N/A
Reduction of Risk	1 2 3 4 5 N/A	Other:	1 2 3 4 5 N/A
Form of Output	1 2 3 4 5 N/A	Other:	1 2 3 4 5 N/A

Waste Sources

Waste of Resources	
Waste of Time	
Waste of Quality	
Waste of Opportunity	
Information Waste	
Other:	

Comments/Suggestions

(improvement ideas, problems, stress points)

Reference: Adapted from the manual prepared by Dr. Hugh L. McManus (2005)

APPENDIX 5: VSM DATA COLLECTION LEGEND

Table 5.1: Data Collection Sheet Legend

Data Collection Sheet Legend	
Elapsed Time: days from authorization to proceed, to the completion of the activity **In-process Time**: hours of active work, as measured, for example, by time charged **Core Task Work Time**: time when core task is being worked, excluding setup, data retrieval, etc.)	**Special Resources Required:** any personnel, tools, or information that may distinguish the activity or provide constraint **Chance of Rework/Time:** percent chance of rework being required for (or because of) the activity, and the time associated with that rework
Input Criteria	
Quality 5 - Significantly more information than needed 4 - More information than needed 3 - Quality is just right 2 - Information is missing 1 - Information is inaccurate and/or untrustworthy	**Formatting** 5 - Ideal formatting for immediate use 4 - Fairly good formatting 3 - Acceptable formatting 2 - Some reformatting necessary 1 - Reformatting necessary
Utility 5 - Direct and critical contribution 4 - Important contribution 3 - Beneficial contribution 2 - Indirect contribution 1 - No contribution	**Transfer:** the method of transfer by which the input arrives to the activity **Output Purpose:** the product that the output is contributing to, or the goal of the activity
Critical Drivers: **metrics that reveal the distinguishing nature and critical drivers of the process**	
Context: **interaction with other Value Streams (such as manufacturing and R&D), and any authority/review issues**	
Value Criteria	
Functional Performance (FP) Functional performance of the end product to be delivered to the customer 5 - Direct specification of major FP parameters 4 - Direct specification of FP parameters 3 - Direct specification of minor FP parameters 2 - Indirect specification of FP parameters 1 - Possible specification of FP parameters	**Form of Output** The form of the output of this task (e.g. report, spreadsheet, build-to-package, etc.) 5 - Flows easily into program milestone 4 - Flows into milestone with some changes 3 - Flows easily into downstream task 2 - Flows into next task with some changes 1 - Flows into next task with major changes
Definition of Processes Definition of processes necessary to deliver the end product to the customer 5 - Direct specification of major downstream processes 4 - Direct specification of downstream processes 3 - Direct specification of minor downstream processes 2 - Indirect specification of downstream processes 1 - Possible specification of downstream processes	**Enabling Activities** Enabling other activities to occur (e.g., the other activity is required for completion of program) 5 - Major checkpoint preventing further work 4 - Moderate checkpoint in program 3 - Task necessary for continued work 2 - Necessary, but not especially time-sensitive 1 - Necessary, but not time sensitive
Reduction of Risk Reduction of risks and uncertainties associated with functional, process, or market areas 5 - Major risks greatly reduced or eliminated 4 - Significant reduction of risks 3 - Minor reduction of risks 2 - Indirect reduction of risks 1 - Possible reduction of risks	**Cost/Schedule Savings** Cost and/or schedule savings resulting from task execution (i.e., a core competency) 5 - Recognized as a core competency 4 - Major improvement over historical predecessor 3 - Improvement over historical predecessor 2 - Minor improvement over predecessor 1 - Possible improvement over predecessor
Waste Sources	
Waste of Resources: possible misuse or non-optimization of resources **Waste of Time:** possible cause for delays, waiting, unplanned rework **Waste of Quality:** possible cause for lack of quality, errors, defects **Waste of Opportunity:** possible oversight of personnel, tool, or technology potential **Info Waste:** overproduction, inventory, transportation, unnecessary movement, over-processing, transfers, scatter	

Reference: Adapted from the manual prepared by Dr. Hugh L. McManus (2005)

APPENDIX 6: COMPLETION TIME OF LM

Table 6.1: The Completion Time of Line Maintenance Process for CSM

No	Unscheduled Process of Line Maintenance	Completion Time (min.)
1	Custom Management Approval	75
2	OCC & Outstation Communication	60
3	OCC & Catering Department Communication	120
4	Customer Complaints Management	60
5	ETOPS Management	60
6	One-Off-Authorization	120
7	SAFA/ SANA Quality Management	60
8	Flight Safety (DFDR)	60
9	Certificate Management	60
10	Civil Authority Coordination	60
11	Occurrence Report	60
12	Trouble shooting	60
13	Late Responses from Cabin Crew for Preflight	120
14	The Replacement of Brake Unit	60
15	The Replacement of Tires	120
16	Defect Rectification	60
17	Cockpit Preparation	60
18	Lamp Defects	60
19	Technic Divert	60
20	Technic Divert (External)	120
21	Precautions for diverted A/Cs	45
22	Material Transfer from Inventory to A/Cs	120
23	Customer Damage WO	60
24	Response to SAFA/ SANA Findings	35
25	Performance Analysis	120
26	AIRMAN/ACARS Document Management	60
27	Precautions for Component Removal	10
28	Component Removal	720
29	Minimum Equipment List Management	120
30	Engineering Order	30
31	Customer Relationship	30
32	Cabin Interior Support	120
33	Stretcher Operation	30
34	Vendor	60
35	Logistics	60
36	Supervisor Support for De-icing	30
37	Official Letters and Special Request from Airline Operator	60
38	Ground Handling Management	120
39	Response to Cabin Crew Call	120
40	Material Transfer from Bulkhead	120
41	Hangar Security	30
42	AOG Management	120
43	Servicing on demand	120
44	Vehicle Transfer	60
45	Hangar Arrangement	90
46	X- Sit	30
	Total	**3900**

APPENDIX 6: COMPLETION TIME OF LM FOR CSM

Table 6.1: Completion time of Line Maintenance Process (Continued)

No	Scheduled Process of Line Maintenance	Completion Time (min.)
47	A Check Planning	30
48	A Check	720
49	Runway Support	60
50	Tool Transfer	90
51	Daily Check	60
52	Weekly Check	180
53	Daily Briefing	60
54	Head Set/Fuel Water Drain Service	60
55	HOT Cup Transfer	60
56	Regular Morning Meeting	60
57	Ramp Check	120
58	Line Check	360
59	Operator Support for Night Shift	60
60	Aircraft Towing	60
61	Total Care Material & Labor Transfer	30
62	The organization of Flying Technician	120
63	The transportation of Flying Technician	120
64	Personnel Transportation	120
65	Aircraft Delivery	60
66	Gate Permission	60
67	Vehicles Services	30
68	Aircraft Document Management	30
		2550
No	**Support Process of Line Maintenance**	**Completion Time (min.)**
69	Invoice Analysis for Rental Component at Outstation	60
70	Warranty Follow-up	30
71	Fuel Support	120
72	Document Scanning Management	60
73	Night Watch	60
74	Aircraft Document Support	30
75	Vendor Coordination	60
76	Hangar Security for Other Customer	30
77	Cabin Galley Support	60
78	Transfer from Main Gate	60
79	Other Personnel Transfer	120
80	AOG Management for Other Customers	360
81	De-Icing Support	60
82	Aircraft Caro Support	120
83	Material and Technician Support for Outstations	60
84	Cockpit Support	120
85	Hangar Communication	300
86	Repetitive Defects Support	180
87	Check Support for Customer Airlines	540
88	Risk Management	120
89	OCC Support	60
90	Response to Flight Crew	60
		2670

Note: Measured Completion Time at the VSM Workshop acc.to VSM Guideline

APPENDIX 7: COMPLETION TIME OF LM FOR FSM

Table 7.1: The Completion Time of Line Maintenance Process for FSM

No	Unscheduled Process of Line Maintenance	Completion Time (min.)
1	Custom Management Approval	40
2	OCC & Outstation Communication	60
3	OCC & Catering Department Communication	120
4	Customer Complaints Management	60
5	ETOPS Management	60
6	One-Off-Authorization	120
7	SAFA/ SANA Quality Management	60
8	Flight Safety (DFDR)	60
9	Certificate Management	60
10	Civil Authority Coordination	60
11	Occurrence Report	60
12	Trouble shooting	60
13	Late Responses from Cabin Crew for Preflight	120
14	The Replacement of Brake Unit	60
15	The Replacement of Tires	120
16	Defect Rectification	60
17	Cockpit Preparation	60
18	Lamp Defects	60
19	Technic Divert	60
20	Technic Divert (External)	120
21	Precautions for diverted A/Cs	45
22	Material Transfer from Inventory to A/Cs	120
23	Customer Damage WO	60
24	Response to SAFA/ SANA Findings	35
25	Performance Analysis	120
26	AIRMAN/ACARS Document Management	60
27	Precautions for Component Removal	10
28	Component Removal	720
29	Minimum Equipment List Management	120
30	Engineering Order	30
31	Customer Relationship	30
32	Cabin Interior Support	120
33	Stretcher Operation	30
34	Vendor	60
35	Logistics	60
36	Supervisor Support for De-icing	30
37	Official Letters and Special Request from Airline Operator	60
38	Ground Handling Management	120
39	Response to Cabin Crew Call	120
40	Material Transfer from Bulkhead	120
41	Hangar Security	30
42	AOG Management	120
43	Servicing on demand	120
44	Vehicle Transfer	60
45	Hangar Arrangement	90
46	X- Sit	30
	Total	**3865**

Note: Measured Completion Time at the VSM Workshop acc.to VSM Guideline

APPENDIX 7: COMPLETION TIME OF LM FOR FSM

Table 7.1: The Completion Time of Line Maintenance Process for FSM (Continued)

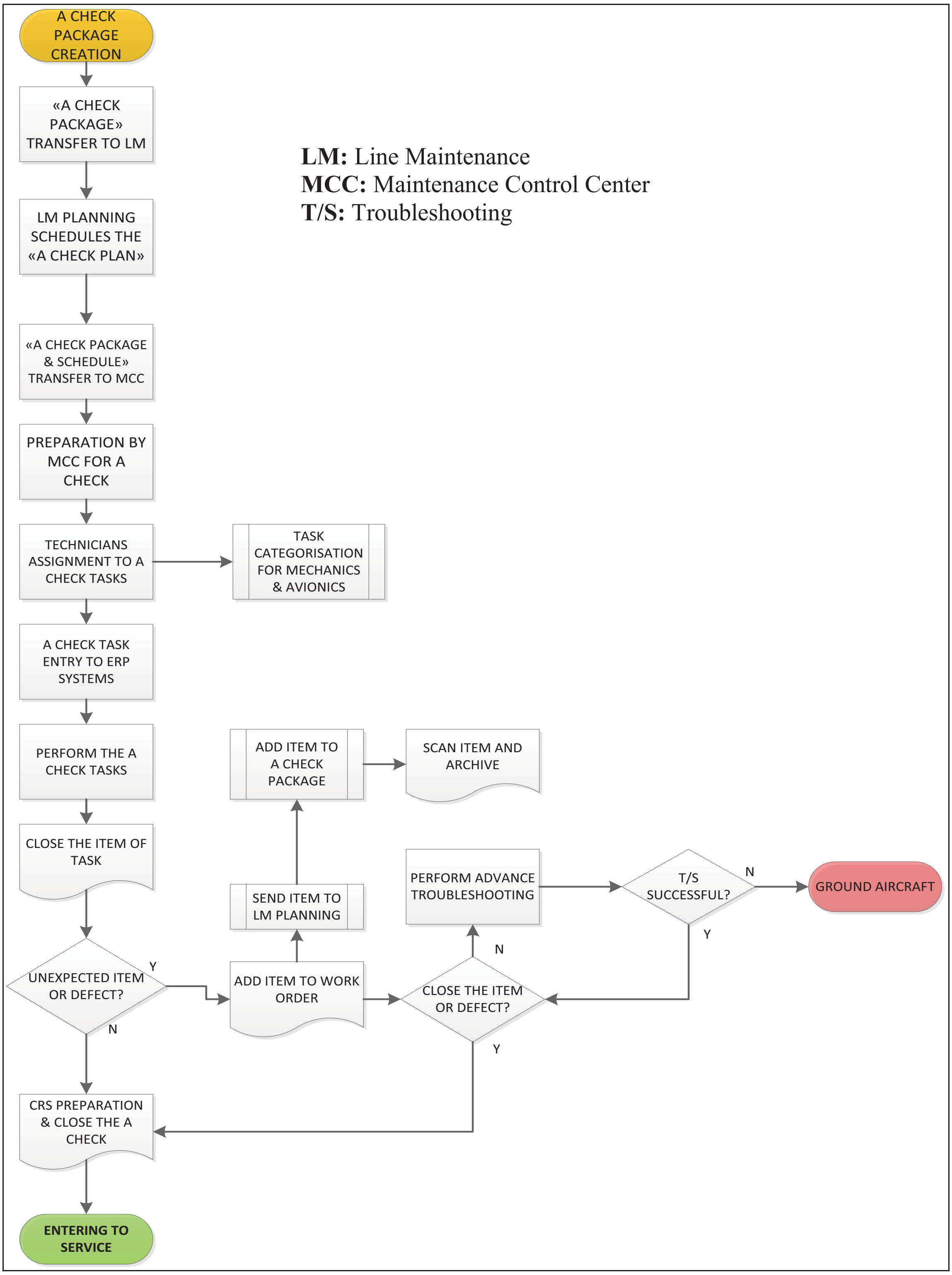
No	Scheduled Process of Line Maintenance	Completion Time (min.)
47	A Check Planning	30
48	A Check	480
49	Runway Support	60
50	Tool Transfer	60
51	Daily Check	60
52	Weekly Check	180
53	Daily Briefing	60
54	Head Set/Fuel Water Drain Service	60
55	HOT Cup Transfer	60
56	Regular Morning Meeting	60
57	Ramp Check	120
58	Line Check	360
59	Operator Support for Night Shift	60
60	Aircraft Towing	60
61	Total Care Material & Labor Transfer	30
62	The organization of Flying Technician	120
63	The transportation of Flying Technician	90
64	Personnel Transportation	120
65	Aircraft Delivery	60
66	Gate Permission	60
67	Vehicles Services	30
68	Aircraft Document Management	30
		2250
No	**Support Process of Line Maintenance**	**Completion Time (min.)**
69	Invoice Analysis for Rental Component at Outstation	30
70	Warranty Follow-up	30
71	Fuel Support	120
72	Document Scanning Management	60
73	Night Watch	60
74	Aircraft Document Support	30
75	Vendor Coordination	60
76	Hangar Security for Other Customer	30
77	Cabin Galley Support	60
78	Transfer from Main Gate	60
79	Other Personnel Transfer	120
80	AOG Management for Other Customers	360
81	De-Icing Support	60
82	Aircraft Caro Support	120
83	Material and Technician Support for Outstations	60
84	Cockpit Support	120
85	Hangar Communication	300
86	Repetitive Defects Support	180
87	Check Support for Customer Airlines	540
88	Risk Management	10
89	OCC Support	40
90	Response to Flight Crew	60
		2510

Note: Measured Completion Time at the VSM Workshop acc.to VSM Guideline

APPENDIX 8: THE PROCESS OF A CHECK

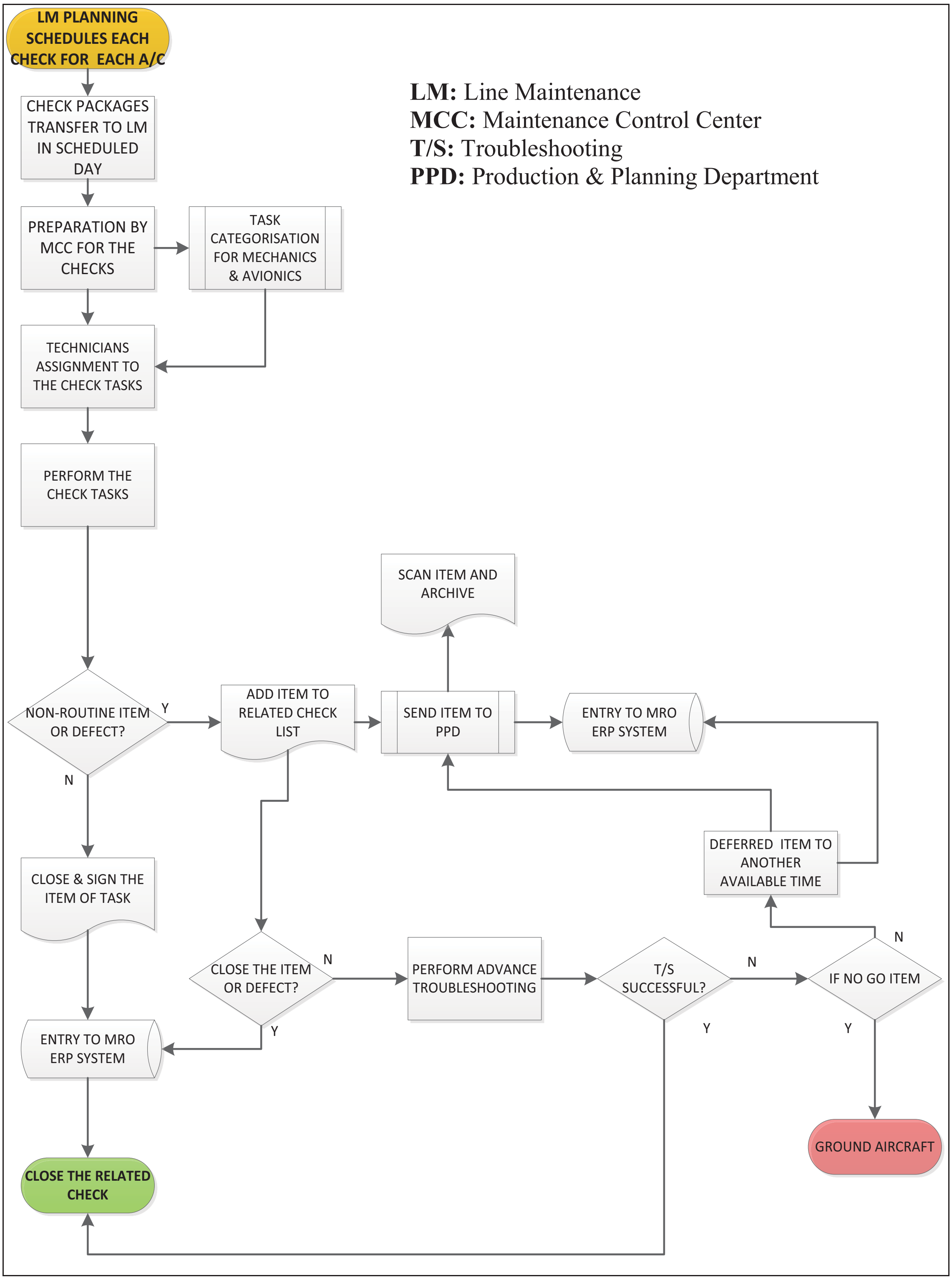
The Process of "A Check"

Figure 8.1: The Process of "A Check"



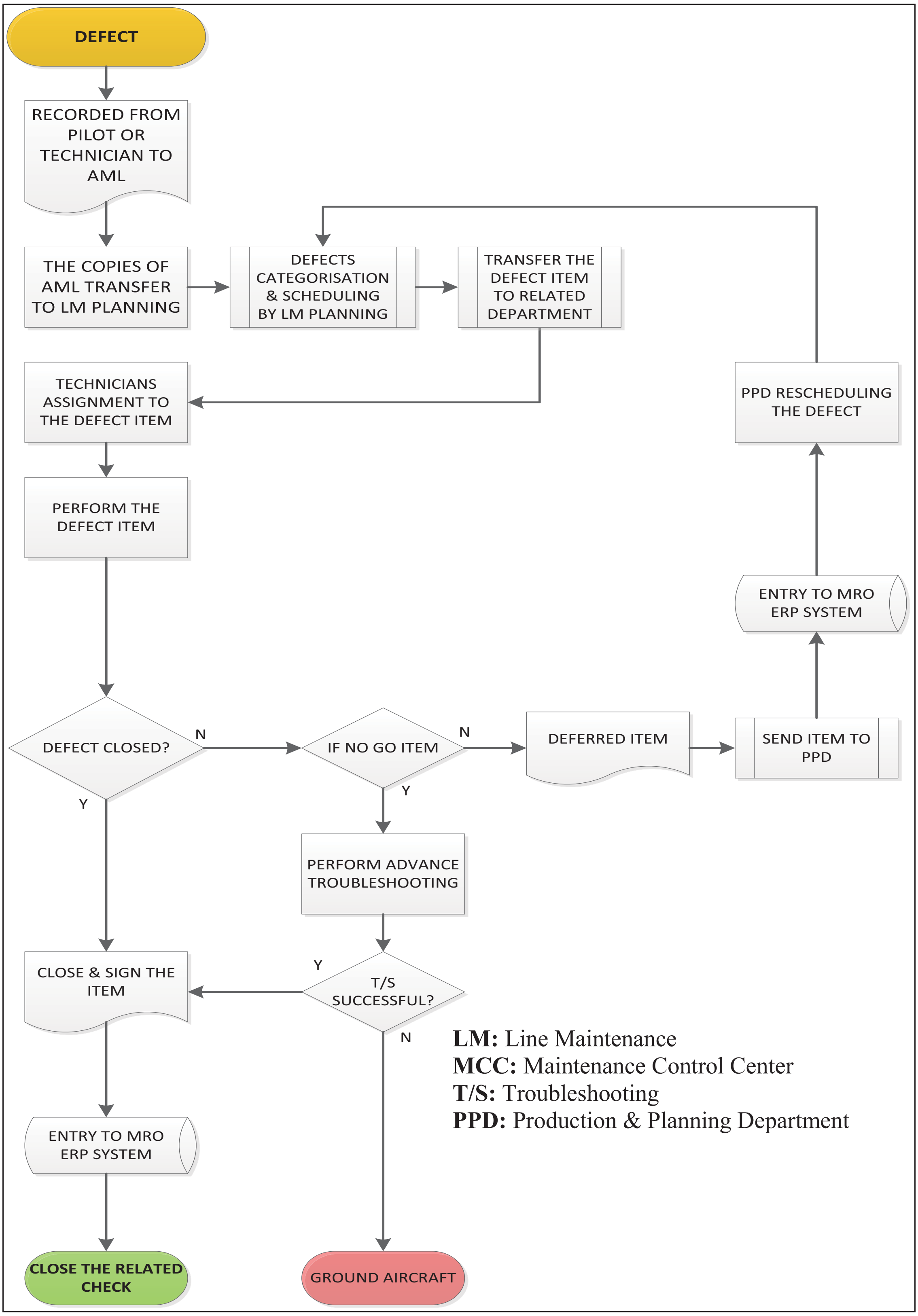
APPENDIX 9: THE PROCESS OF TRANSIT/RAMP/WEEKLY CHECK

Figure 9.1: The Process of "Ramp/Transit/Daily/Weekly Check"



APPENDIX 10: THE PROCESS OF TROUBLESHOOTING

Figure 10.1: The Process of "Troubleshooting"



APPENDIX 11: VSM WORKSHOP FOR CSM

Figure 11.1: Visio CSM View from Workshop

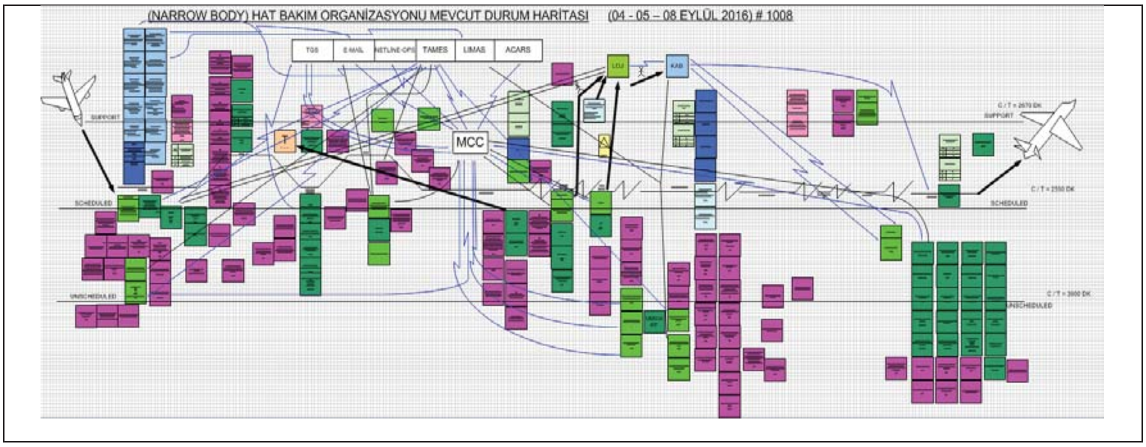
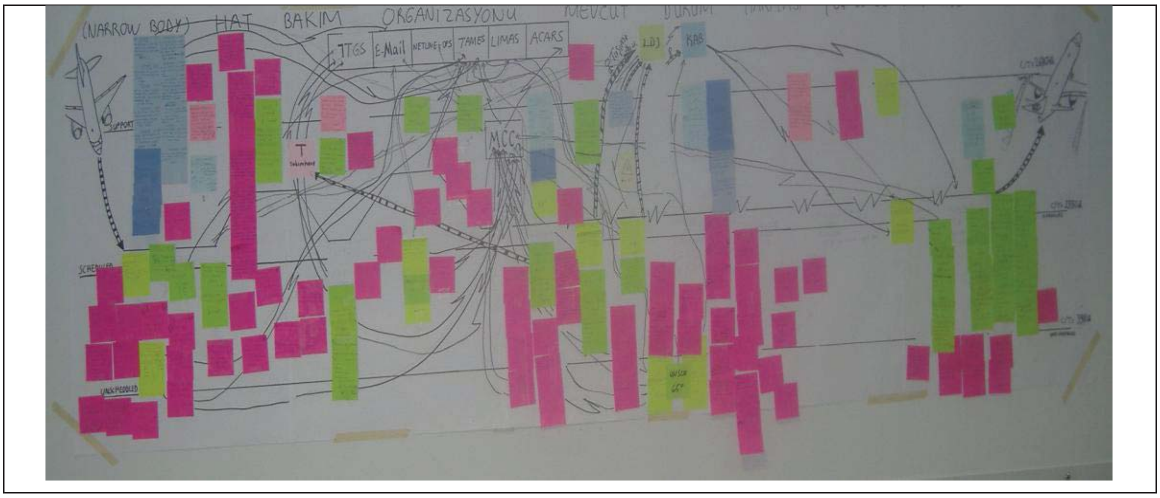


Figure 11.2: Real CSM from Workshop



APPENDIX 12: VSM WORKSHOP FOR FSM

Figure 12.1: Visio CSM View from Workshop

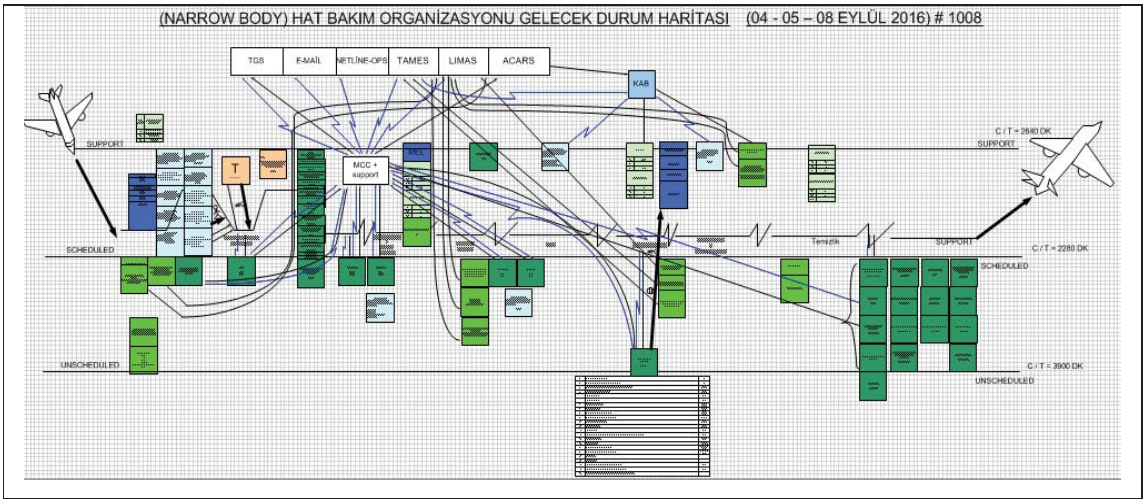


Figure 12.2: Real FSM from Workshop

APPENDIX 13: VSM WORKSHOP CHARTER DOCUMENT

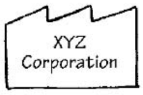
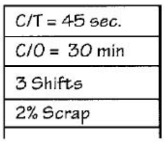
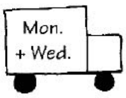
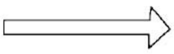
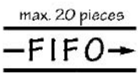
Table 13.1: A Template for VSM Charter Documents

DEFINITION				
CURRENT STATE				
CONSTRAINTS		*TIME*	*COST*	*SCOPE*
	KEY DRIVER			
	WEAK REQUIREMENT			
SCOPE				
DELIVERABLES				
BOUNDARIES				
CTQ				
TEAM COACH, LEADER				
TEAM MEMBERS	*GROUP 1*	*GROUP 2*	*GROUP 3*	*GROUP 4*
MEMBER 1				
MEMBER 2				
MEMBER 3				
MEMBER 4				
MEMBER 5				
MEMBER 6				
MEMBER 7				
MEMBER 8				
DURATION				
BUDGET				
TOOLGATES, MILESTONES				
APROVAL DATES				

LEADERSHIP APPROVAL
NAME SURNAME
DATE
SIGNATURE

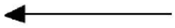
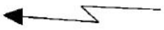
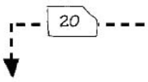
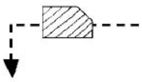
APPENDIX 14: VSM ICONS

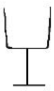
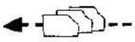
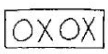
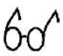
Material Icons

Material Icons	Represents	Notes
	Manufacturing Process	One process box equals an area of flow. All processes should be labeled. Also used for departments, such as Production Control.
	Outside Sources	Used to show customers, suppliers, and outside manufacturing processes.
	Data Box	Used to record information concerning a manufacturing process, department, customer, etc.
	Inventory	Count and time should be noted.
	Truck Shipment	Note frequency of shipments.
	Movement of production material by <u>PUSH</u>	Material that is produced and moved forward before the next process needs it; usually based on a schedule.
	Movement of finished goods to the customer	
	Supermarket	A controlled inventory of parts that is used to schedule production at an upstream process.
	Withdrawal	Pull of materials, usually from a supermarket.
	Transfer of controlled quantities of material between processes in a "First-In-First-Out" sequence.	Indicates a device to limit quantity and ensure FIFO flow of material between processes. Maximum quantity should be indicated.

APPENDIX 14: VSM ICONS

Information Icons

Information Icons	Represents	Notes
	Manual Information Flow	For example: production schedule or shipping schedule
	Electronic Information flow	For example via electronic data interchange.
	Information	Describes an information flow.
	Production Kanban (dotted line indicates kanban flow)	The "one-per-container" kanban. Card or device that tells a process how many of what can be produced and gives permission to do so.
	Withdrawal Kanban	Card or device that instructs the material handler to get and transfer parts (i.e. from a supermarket to the consuming process).
	Signal Kanban	The "one-per-batch" kanban. Signals when a reorder point is reached and another batch needs to be produced. Used where supplying process must produce in batches because changeovers are required.

	Sequence-Pull Ball	Gives instructions to immediately produce a predetermined type and quantity, typically one unit. A pull system for subassembly processes without using a supermarket.
	Kanban Post	Place where kanban are collected and held for conveyance.
	Kanban Arriving in Batches	
	Load Leveling	Tool to intercept batches of kanban and level the volume and mix of them over a period of time.
	"Go See" Production Scheduling	Adjusting schedules based on checking inventory levels.

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