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Applying Lean to the AC-130 Maintenance Process for the Royal Saudi Air Force

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APPLYING LEAN TO THE AC-130 MAINTENANCE PROCESS FOR THE ROYAL SAUDI AIR FORCE

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APPLYING LEAN TO THE AC-130 MAINTENANCE PROCESS FOR THE ROYAL SAUDI AIR FORCE

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APPLYING LEAN TO THE AC-130 MAINTENANCE PROCESS FOR THE ROYAL SAUDI AIR FORCE

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Abstract

The ideas expressed in this research come from the researcher's experiences working in the AC-130 maintenance squadron in the Royal Saudi Air Force. The research focuses on improving the AC-130 maintenance process in the Royal Saudi Air Force.

The AC-130 maintenance process needs to improve cycle time and reliability, improve safety, and improve availability of aircraft. This can be done by improving communication, reducing distances needed to move or transport equipment during the maintenance process and by efficient use of the available qualified workforces, tools, and equipment.

Consideration is given to applying existing management techniques to the Royal Saudi Air Force's AC-130 Maintenance Squadrons. Once reviewed, the selected technique for this research was the "Lean" management approach. The research suggests that Lean can help and improve AC-130 maintenance processes in the Royal Saudi Air Force for several reasons. The purpose of Lean is to reduce costs, eliminate waste, increase efficiency, improve product quality, maximize value to the customer and provide greater availability and quicker maintenance turnaround of C-130s. Theoretically, by applying Lean plans, there will be reduction of 65% - 96% cycle time. There are five basic processes that need to be improved, but the bottom line benefit that the research suggests is to minimize the time required to maintain the aircraft C-130 and improve the availability rate.

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My eternal love and gratitude to my wife, for your priceless love, support, understanding, and words of encouragement that have always made me reach farther.

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APPLYING LEAN TO THE AC-130 MAINTENANCE PROCESS FOR THE ROYAL SAUDI AIR FORCE

I. Introduction

Background

The implementation of the Lean process improvement approach within organizations has become very popular in recent years. Since early pioneers invented machines that enabled and improved mass production, others have taken additional steps forward, such as creatively applying statistical methods to analyze processes and improve quality by reducing variation within processes. Today, some companies focus their Lean efforts on maximizing the quality of their products and services in order to improve customer satisfaction, while others use Lean as a mechanism for driving down costs. Still others aim to change the culture within their organization to one that rewards its members for sharing ideas that continually improve their internal business processes and policies.

In general, the purpose of Lean is to reduce costs, eliminate waste, increase efficiency, improve product quality, and maximize value to the customer. This is true for profit and non-profit organizations alike. For the Royal Saudi Air Force, the desired effects of Lean is to have Smart operations, increase productivity of its personnel, increase critical asset availability, improve response time, maintain safe and reliable operations and improve energy efficiency.

Problem Statement

The AC-130 maintenance squadron is subordinated under the logistic wing, the maintenance process is not currently being used as effectively as it could be to make AC-130 fully mission capable. This is not happening because of lack of knowledge, manpower, tools and equipment. This happens because the current maintenance process is not managed the way that gets the work done as soon as possible. This conflicts with the mission of the AC-130 aircraft, which is to be ready to react fast when needed.

Maintenance and parts availability are the main factors which keep AC-130 aircraft flying. Having a good maintenance process which can perform in a shorter time would be beneficial for the Royal Saudi Air Force. This thesis presents lean as a solution to improve the maintenance process since lean principles suggest that any process can be improved. In other words, the question is: how can lean be used to truly make a difference for the Royal Saudi Air Force?

Why Does Maintenance Take So Long?

Each aircraft has a daily mission schedule which may require multiple flights. At a given point of time all of the aircraft are fully mission ready. However, over a period of days, the number of aircraft that are fully mission ready starts to fluctuate and the number of available mission ready aircraft decreases. The time needed to fix all of the aircraft increases resulting in extended maintenance times which may continue into the next day. Within a few days, extra work is required to complete the required maintenance to bring all aircraft to flight status.

The time spent in C-130 maintenance process preparing the aircraft makes the aircraft useless during that period of time. It is possible that these issues combine and result in causing this state of affairs.

Repeating other departments' work also increases process time. For example, consider the material office in the C-130 Aircraft Generation Flight. This office mediates between the Maintenance Squadron and the Supply Squadron. Some parts are available but because of the material office's process the part will not come as soon as possible. In some cases, like changing shifts between material staff and supply staff, the delay could be four hours.

Even something as simple as searching for information amongst the various departments delays work completion. Shift changes and having many people independently receiving the information makes the information easy to lose. Adding to that, in some cases, it is often difficult to reach some people or departments because there is no central point of contact or inefficient use of the office lines, radios or even internal networks.

The different goals and priorities for each department or shop lead to a lack of cooperation between them. Because of this, the main goal for the Royal Saudi Air Force may be lost in the process. One of the most important goals for the Royal Saudi Air Force is the readiness of its aircraft. Through such loss of focus on the final purpose of the maintenance process, one department can make the Royal Saudi Air Force lose an aircraft for a day by mistakes in documentation or because they have their own rules and they need to do the job their own way.

All of these issues and impediments lead to the C-130 maintenance process requiring more time and results in crews working late or on weekends. It is obvious, but important to notice, that these issues have nothing to do with the tools that have been used to maintain the aircraft or the quality of the maintenance performed. They are management problems which can be avoided.

The consequences of these issues lead to an increase in the work and pressure on the maintenance squadron workers and employees which could affect their morale. Shortening work hours by using the Lean techniques may result in reducing the stress that workers feel. Another important affect for reducing the work hours is increasing readiness time for the aircraft which is one of the Royal Saudi Air Force main goals.

Research Focus

The purpose of this research is to find a way to use Lean tools to go from simply saving money here or cutting man-hours there to solving the bigger issue of improving the Royal Saudi Air Force AC-130 maintenance process.

Since the Air Force is a nonprofit government entity, its bottom line is mission performance. Lean techniques will be used to shorten the time for process and to develop better ways to accomplish the mission**.**

Research Objectives

The purpose of this research is to find a way to use Lean tools to improve the Air Force's maintenance process.

The most important objective is to minimize the time spent during the Royal Saudi Air Force AC-130 Maintenance process. Meeting the previous objective helps achieve another objective, which is increasing the mission capability of the aircraft.

Research Question

What impact does Lean Processes have on the RSAF AC-130 maintenance process?

Methodology

Traditional maintenance management practices will not address the future business needs. Lean has potential to significantly improve performance, but there are unique challenges associated with their successful implementation.

This research provides specific target areas where Lean should be applied to improve the bottom line of an organization. It uses questionnaires as a way to collect the data. Questionnaires are given to different AC-130 shops for response. The idea of these questionnaires is to determine if Lean could help improve the process. To discover the unnecessary steps, workers can easily identify and consider waste. After collecting the data, information will be analyzed and Lean techniques are used to develop process improvements. In Chapter 2, the research begins by a literature review of Lean methodologies. In Chapter 3, the previous concepts are combined to establish a methodology for effectively employing Lean in an organization. Chapter 4 details the analysis performed and results achieved through application of the methodology to an AC-130 squadron. Chapter 5 is a discussion of the results and wastes identified. Finally, recommendations for further study and future implementation are provided.

Assumptions and Limitations of the Study

This research deals with the available resources and will not go into any financial matters or administration process. It focused on the maintenance squadron and has no interaction with any other squadrons outside the Logistic Wing.

Implications

This research will help in improving the AC-130 maintenance process in the Royal Saudi Air Force Maintenance Squadron by shortening the process time through the more efficient use of resources.

Scope

The methodology presented in this paper is applicable to any organization, which, by definition, is any entity that pursues collective goals, controls its own performance, and has a boundary separating it from its environment. This includes profit and nonprofit organizations. The Royal Saudi Air Force's AC-130 maintenance squadron was examined as a case study for a specific application of the proposed methodology.

II. Literature Review

Overview

This chapter explores theoretical perspectives and previous research findings that can help in developing a tailored response for the analysis to be performed in this research. It contains aspects, such as some key methods available (Lean, Six sigma, Lean six sigma, Business Process Reengineering and Theory of constrains). The purpose of this literature review is to provide a foundation for the discussion about using Lean for the AC-130 maintenance process. It briefly introduces some common Lean methodologies. It also presents an overview of the salient material investigated while researching the problem statement of this thesis.

Lean

The fundamental premise of Lean is the elimination of Muda, or waste, in the workplace. Waste can be defined as "any activity that consumes resources but creates no value" (Womack, 2003). According to the best-selling book *The Toyota Way*, there are eight types of waste in the workplace: overproduction, waiting, unnecessary transport and conveyance, over processing (or incorrect processing), excess inventory, unnecessary movement, defects, and unused employee creativity (Liker, 2004). The purpose of being Lean is to be able to identify and remove these types of waste to "do more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want" (Womack, 1990). Lean production is based largely on the Toyota Production System, Toyota's unique approach to manufacturing that allows them to use "fewer man-hours, less inventory (to produce) the highest quality cars with the fewest defects of any competing manufacturer" (Liker, 2004). Toyota pioneered this system after World War II during a time when American companies Ford and GM were using mass production and large equipment to produce as many parts as possible as cheaply as possible. Toyota, however, had a much smaller customer base, and had to produce a variety of vehicles in small quantities using the same assembly line. They realized that keeping lead times short and focusing on flexible production lines actually resulted in higher quality, better productivity, and better utilization of equipment and space (Womack, 1990). They were, in effect, doing more with less. The fundamental tenets of Lean production are value, the value stream, flow, pull, and perfection.

Value is defined by the customer as the good or service that is being produced. The value stream refers to the series of sequential steps that the value takes through a process to reach its finished state when it is ready to be given to the customer.

Lean is a technique of creating value with a focus on the elimination of waste. It is all about delivering the need of the customers and what they want; paying the shareholders back what they invested the way they expected; and worker's job satisfaction with lifetime learning that they deserve. Lean thinking helps by giving ways to identify value, reorder value-creating actions in the best way, doing the actions more effectively than before without interruption when they are requested. Lean delivers and figures out a way to do more with less time, human effort, equipment and less space. It results in giving the customers what they exactly want.

Lean thinking includes five major steps (Murman & Allen, 2002). They are:

1. Specify Value:

From the end customer point of view, Lean starts by identifying the 'value' in terms of specific services and products, with specific capabilities and prices for specific customers.

2. Identify the Value Stream:

A ‘value stream’ is the linking of all actions and steps in the processes which are important and necessary to change the raw materials into the final finished products that the customer wants and needed. After that, the customer is supported by providing post sale activities.

3. Make Value Flow Continuously:

After eliminating wasteful actions as completely as can be done along the value stream, the firms should try to make the remaining value creating steps ‘flow’. The challenge is how to get rid of the batch and queue mentality that is common in mass production and install small lot production mentality instead, with single unit batch sizes as the ultimate goal. The best way to create flow is by eliminating traditional functional organizations, replacing them with integrated product teams organized along the value stream.

4. Let Customers Pull Value:

It is the customer who pulls the product from the enterprise instead of the enterprise pushing the product to the customer. By using and performing the Kanpan system, a production system is organized based on the “just in time” principle. The job of total quality management roots out all defective work.

5. Pursue Perfection:

Firms that have applied Lean principles and exercises find that there is no end to the process of minimizing waste. They keep on developing products and services delivered for the customer. So, in terms of eliminating waste and reducing effort, time, space, and errors, the pursuit of perfection entails a continuous process of improvement.

Principles of Lean Enterprise Value (Murman & Allen, 2002):

• Principle 1:

By doing the job right and by doing the right job Lean value is created.

• Principle 2:

Value should be delivered only after knowing stakeholder value.

• Principle 3:

The only way to fully realize Lean value is by adopting an enterprise perspective. The overall net gain will be limited if Lean is not integrated as part of an overall enterprise strategy.

• Principle 4:

To increase Lean, the interdependencies value should be addressed across enterprise levels.

• Principle 5:

People, not just processes, influence Lean value. Lean enterprise value is constrained when workers are not thankful for the knowledge that they have in their roles and experiences.

The main lean tools and techniques are 5S, VSM and JIT. They are described below:

1. **The Five S's:**

There are five Japanese words beginning with the letter S used to make a workplace fit and suited for visual control and Lean production. The five S's indicate personal discipline, habits, and organizational loses that make it easier and helpful to identify the waste (Gapp, R., Fisher, R., Kobayashi, K., (2008)) .

1. Seiton (neatness):

Simplify or sort: take out unimportant things from the work places.

2. Seiri (organization):

Straighten or simplify: arrange tools, paperwork and accessories.

3. Seiso (cleaning):

Scrub or shine: repair, clean and keep clean.

4. Seiketsu (standardization):

Standardize or stabilize: start and keep controls and standards.

5. Shitsuke (discipline):

Sustain or self-discipline: pursue continuous improvement.

Benefits of 5S include removal of any unnecessary tools or material, and efficient organization of the remaining necessary items to ensure that minimal effort is needed to retrieve and utilize tools. Use of shadow boards for hanging tools is an example of 5S implementation in a workshop. Although originally considered a tool for management of workshops, 5S principles can also be applied to portable work environments such as maintenance trucks and job boxes. A large challenge, and the key to successful 5S implementation, is sustaining the efficient workplace organization once it is created. This requires discipline and an ongoing effort. A related term (6S) includes safety with the other five elements to account for the need to improve environmental safety and occupational health (Gapp et al., 2008).

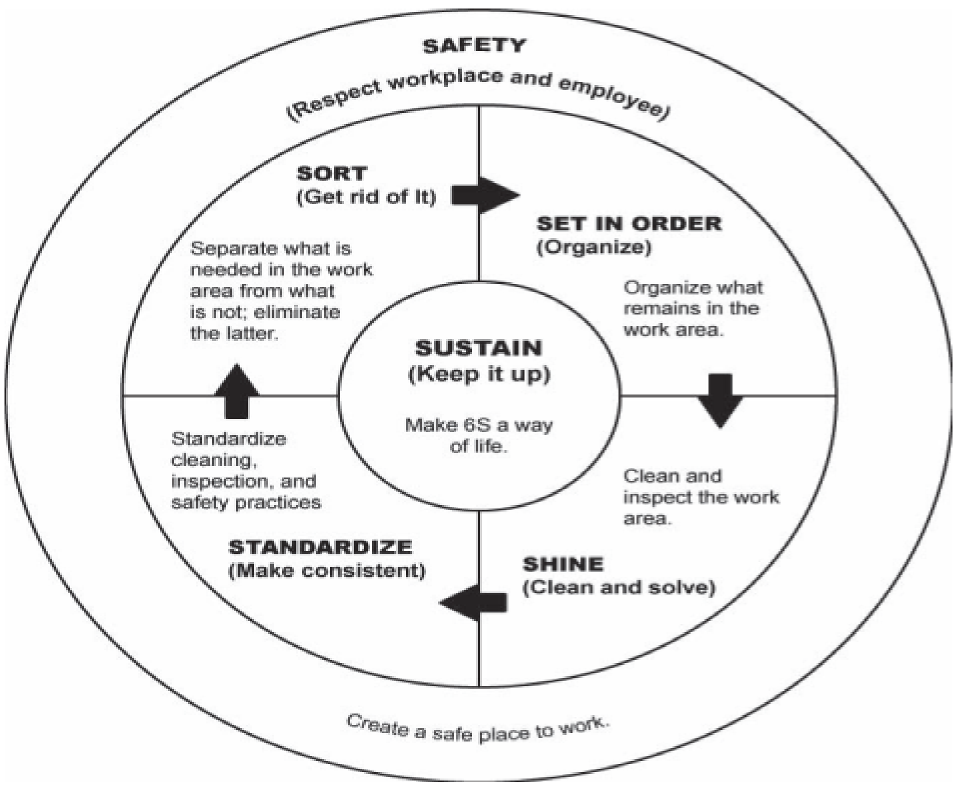

Figure 1. 5s+safety (6s) diagram (EPA, 2011)

2. Just-in-Time (JIT):

It is a Lean technique that focuses on the continuous process of eliminating waste and improving productivity. Waste is defined as any activity that does not add value to the products/services created. Typical examples of wastes are excess lead times, overproduction, and scrap. JIT may be thought of as a 'pull' activity based on customer demand rather than pushing products based on projected demand. The main objective of JIT is to "produce and transport just what is needed, just when it is needed, in just the amount needed, within the shortest possible lead time" (Lai, Kee-hung & Cheng, T.C. Edwin, 2009).

Some of these cultural characteristics are: The Japanese culture emphasizes 'customer orientation' and thus most of the business organizations in Japan operate using a pull strategy. This is seen in how JIT management results in meeting customer demand regardless of the level of demand, the reduction of time as a waste is also part of the JIT management. This means that there is a reduction in time elapsed from the arrival of materials, to the processing and assembling of the final product. This may be as a result of the Japanese emphasis on speed and efficiency. JIT management results in a reduction of inventory and thus enabling more space for the utilization of company processes. JIT ties in with the Japanese concern for space as it is a densely populous country. Yet another element of JIT management is the requirement of keeping the company clean so as to avoid any hindrances to production. Due to limited space, the Japanese culture is concerned with the cleanliness of their environment (Lai et al, 2009).

JIT management can only work effectively if machine changeovers are reduced significantly so that manufacturers upstream continuously produce small amounts of parts at the rate they are required by the next process downstream. Also the downstream production should practice level scheduling so as to create a smooth day-to-day order flow that is free from any changes or problems that are unrelated to actual customer demand. When implementing JIT techniques in a company, it is important to first have an agreement and support with all those who may be involved, typically those who work in the company, and companies involved within the supply chain. It would be impossible for a company to implement JIT without the support of its suppliers. For example, as JIT affects replenishment lead times and order cycle times which would affect the suppliers. “In sum, JIT is based on the concept of delivering raw materials just when needed and manufacturing products just when needed” (Lai et al, 2009).

3. **Value Stream Mapping:**

Value Stream Maps are maps that show all the specific action that occurred along a value stream for a product or service. In eliminating waste, value stream mapping proves to be a useful tool to decrease cost and time to meet customer demands. It can work as a very useful tool in identifying process activity or steps that can be improved to ‘do the job right’. The value stream map visualizes interactions and flows between steps and shows linkages between information and product flows. It helps to identify the constraints and wastes in process as well as the process sources (Gardiner, 2008).

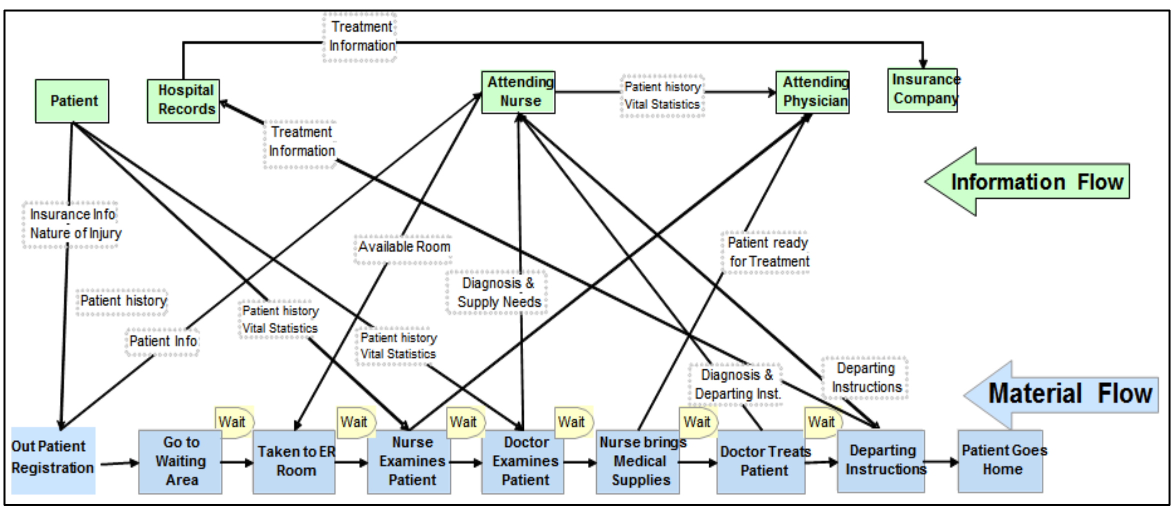

Figure 2. Example of VSP in Emergency room (Gardiner, 2008)

Figure (2) shows an example of using the value stream process in an emergency room where the information and material flow are shown in every stage of the process.

There are some key methods other than Lean that are available and can be used with the maintenance process, and are described in brief below:

Six Sigma

While Lean focuses on making a process more efficient, Six Sigma is a methodology used to improve product quality. Six Sigma is defined as a comprehensive and flexible system for achieving, sustaining and maximizing business success (Pande, 2000). Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes (Pande, 2000). Six Sigma was embraced by the Motorola Corporation as a method of improving customer satisfaction by increasing product quality. Sigma (σ) is a term in statistics that refers to the amount of variation of data points from the mean in a data set. Within the context of a normal distribution, this means that 99.99998% of all data points are within six standard deviations (six sigma) from the mean (Figure 3). In business terms, this can be quantified as operating with only 3.4 defects per million opportunities, where a "defect" is defined as any instance or event in which the product or process fails to meet a customer requirement. A company that is able to fine-tune its products and processes to this level will be near-perfection in meeting customer requirements (Pande, 2000).

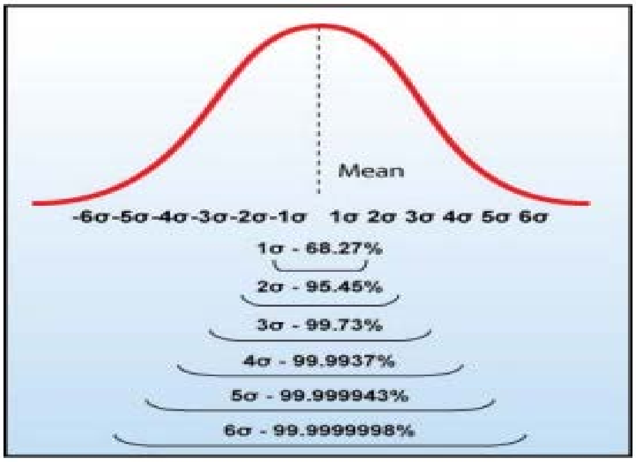

Figure 3. "Six sigma" deviations from mean (Pande, 2000)

One of the biggest advantages of using Six Sigma lies in the methodology statements which assert that “no project shall be approved if a bottom line impact has not been clearly defined” (Pande, 2000). Other benefits include: emphasis on achieving attainable goals, implementing projects that will produce results, and using information that has real world meaning.

While Six Sigma is rapidly spreading throughout a variety of industries and organizations, some limitations can be said to exist within its procedures and measurements. Projects which are directed are selected by organizations subjectively rather than objectively, which means that goals may be mistakenly thought of as attainable and favorable when in fact they may eventually be a waste of resources and time. In order to keep this from happening further, the Six Sigma community must come together and stand up for strict training and certification standards to be issued throughout (Pande, 2000).

Lean Six Sigma

Lean Six Sigma, as the name implies, combines Lean and Six Sigma to achieve greater process improvement gains. The purpose of Lean is to minimize waste (increase efficiency) and that of Six Sigma is to reduce variation (increase effectiveness). The result of the combination is the customer will receive a defect-free product faster. In general, Lean techniques will result in more immediate gains. Improvements from Six Sigma application will take longer. Using the methods together will maximize productivity and ensure customers are getting what they need, when they need it (George, 2002). Lean and Six Sigma principles can be applied to logistics and supply chain operations (Goldsby, Martichenko, & Goldsby, 2005).

Benefits of using Lean Six Sigma include:

- Deeply linked with the project
- Takes an active role in critical processess like change request management

Some limitations of using Lean Six Sigma:

- More than an Initiator
- Needs training

Business Process Reengineering

Reengineering is defined as the fundamental rethink and radical redesign of business processes to generate dramatic improvements in critical performance measures such as cost, quality, service and speed. The basic idea is to start with a blank sheet of paper, forget about current processes and traditions, take what is known about customers and their preferences, and develop completely new “optimized” business processes. The goal is to produce simplified business processes, empowered personnel, and a shift of emphasis from individual to team achievements. Challenges associated with BPR are poor leadership, poor or inconsistent communication and exclusion of current employees (Hammer, 2003).

Theory of Constraints

The Theory of Constraints (TOC) is based on the idea that quality and productivity will increase if various constraints are removed. The philosophy emphasizes that a single constraint or bottleneck exists in any process and controls the output from the entire process. A constraint is anything that hinders an organization in reaching its goals. There are two types of constraints: physical and nonphysical. Some examples of physical constraints are warehouse space, machine capacity, or number of delivery vehicles. Some examples of non-physical constraints are employee attitudes, customer demand, or company procedures. Each type of constraint must be identified, categorized, and treated accordingly in order to manage performance. TOC can be applied to manufacturing processes, such as inefficient factory layouts, wrong quantity or type of inventory, or schedule problems, and to management processes, such as outdated policies or procedures (Cox & Schleier, 2010).

TOC uses a six-step process to enable ongoing improvement:

1. Identify the system’s constraints

2. Decide how to exploit the system’s constraints

3. Subordinate everything else to the decision in step 2

4. Elevate the system’s constraints

5. If the system’s constraints were changed, return to step 1

6. Change the system if required

A benefit of using TOC is the optimization of productivity and customer satisfaction and the challenge of using TOC is that it primarily focuses on short-term profit maximization.

Why to use Lean in the Air Force?

Lean has ways and techniques for solving and finding solutions. Lean does not depend on one man's decisions. Lean is a management method based on rules and a system. Lean needs analysis and understanding before applying it. In addition, it is not hard to do. It is well understood and it is rational.

Another reason to use Lean is that the aerospace industry has started to use it and the Royal Saudi Air Force is a customer of companies in that aerospace industry. One reason that cannot be neglected is the use of Lean by other Air Forces around the world. The US Air Force developed a system called AFSO21 which is about applying Lean in the US Air Force. The US Air Force even developed a manual for AFSO21 to show each department how it should use Lean to work. The existence of AFSO21 and the application of Lean in US Air Force make seeing the improvement due to Lean in a similar air force environment easier. This is especially true, if that air force is the world's number one Air Force. It should be remembered that most of the Royal Saudi Air Force systems and regulations were adopted from the United State Air Force. That should make AFSO21 one of the most important referenced documents mentioned in this research.

Examples of companies and organizations that have used Lean:

Aerospace industries:

In the early 1990s the US Aerospace industries started with Lean when companies and government reacted to post-cold war imperatives. The first application of Lean in aerospace was in aerospace manufacturing. The lessons were taken from the initiatives of the automobile and electronics companies' large productions, then moved and applied to aerospace field (Murman, 2004).

The Lockheed Aeronautical Systems Company:

In the late 1980s, Lockheed founded a strategic planning team for applying Lean to improve the company performance and eliminate waste. The team modified the available area to become a redesigned factory by using a new delivery system for components and tooling and a new scheduling system. The team improved store-to-stock production times to 11 days instead of 65 days. It also reduced the work in process to 2 days instead of 35 days (Murman, 2004).

AFSO21:

The United States Air Force knows how Lean is important for improving work. Therefore USAF started the Air Force Smart Operations for the 21st Century (USAF, 2008) which enabled successful rapid improvement. The vision for AFSO21 is to start a continuous process improvement (CPI) environment whereby all airmen are actively getting rid of waste and continuously improving processes AFSO21 is a way to see where the wastes are and eliminate them in any area. It is also an operating principle that simplifies the way material and information flow (Sabol, 2008).

Robins Air Force Base (United States Air Force) has executed many of different Lean projects that have had environmental results. Consider the following examples:

• C-5 Maintenance Shop: Lean improvements in the C-5 cargo plane shop:

"Flow days" reduced from 360 to 220 days. Resource productivity improved by 30-50 percent. $8 million saved in the first year. These developments minimized raw material consumption, use of hazardous chemicals, and waste related with the C-5 maintenance processes" (Barrett & Fraile, 2004).

• C-130 Aircraft Paint Shop: by using 6S techniques (Straighten, Sort, Shine, Standardize, Sustain, and Safety) Robins Air Force Base developed and improved the paint system for C-130 Hercules aircraft. By using many Lean events, RAFB increased production, reduced flow days, increased safety awareness in workers, and reduced volatile organic compound emissions, storage space, and chemical use (Barrett & Fraile, 2004).

Chapter summary:

In summary, different concepts to improve maintenance processes were undertaken and summarized. In addition, Lean concepts were discussed. Lean principles are used for the following reasons:

• They can be applied at all levels and in any type of organization.

• When they have been understood, Lean will spread quality quickly.

• They help other approaches and make them more effective if launched.

• They build a culture of continuous development.

Finally, issues associated with potential implementation in maintenance are discussed, with some company and organization examples.

The fundamental concept of Lean maintenance is to remove waste from all processes and activities (at any level). Identifying the value stream map is a fundamental concept to Lean implementation. It is important to emphasize that implementing Lean is not so much a program as it is a discipline, set of practices, or mind-set. Questionaries' are used to understand the current situation at the Royal Saudi Air Force. Chapter 3 will discuss the way of using VSM and Questionnaires.

III. Methodology

Overview

This chapter provides details about data collection and the methodology used for analysis. This chapter presents a methodology for identifying how and where to use Lean processes in the C-130 maintenance squadron.

Data Collection

Lean maintenance will be described starting with a high-level definition, followed by a discussion of related elements. The fundamental concept of Lean is not difficult to understand; however, the practical deployment of these concepts involves many challenges. Lean describes a philosophy, not a new process to replace the current reliability initiatives. Lean maintenance refers to the practice of reducing waste in all processes and tasks relating to production asset maintenance. Lean practices can apply to a number of maintenance process elements, ranging from work management to inventory management to root-cause analyses, just to name a few.

In order for an organization to implement Lean methods effectively, it must have the right objective from the outset. Contrary to popular belief, the ultimate goal of Lean is not to simply save money or reduce man-hours (though these are certainly positive side effects). For an organization to achieve success it must go much deeper than these "symptoms" and examine its sole purpose for existence: it must identify its bottom line (Degenhardt, 2011).

For a Lean event to have the most success with lasting results for a company, the target for improvement must be the bottom line, which is to increase profit. The military, however, does not work for profit, so how do we define our bottom line? According to Sink and Tuttle, improving performance is the bottom line (Phusavat & Photaranon, 2006).

Questionnaires were used to gather the data for this thesis. All feedback answers were saved on Microsoft Excel 2010. We have selected the AC-130 Propulsion Maintenance Group at Prince Sultan Air Base as our study population. The AC-130 maintenance squadron is comprised of approximately 1,600 military and civilian personnel.

Questionnaires were written in the Arabic language because the questionnaires were given to Saudi Air Force staff that might have some difficulties in understanding the English language and the goal was to get answers without language obstacles that could prevent them from explaining answers in full detail. Questionnaires were administered and collected over a nine month period by RSAF personnel and returned to the researcher.

We collected primary data by questioning people from 15 different shops. Participants and groups were selected from different shops, different job experience and different ranks.

Five questionnaires were developed for different purposes. One of the questionnaires was made for Aircraft Maintenance Administration staff. Three of the questionnaires were for the AC-130 Maintenance Aircraft staff. The last one was for the customers of the AC-130 Maintenance Squadron which is the Operations Squadron. The questions were written in different ways; some were yes or no questions while others were short answer questions to give a chance to the participants to share their own ideas.

Questionnaire No.1

Questionnaire number 1 investigates if there has been any attempt to apply Lean in one of the AC-130 maintenance processes in the past or currently. Questionnaire number 1 looked for how the AC-130 maintenance process should be performed step-by-step based on the Royal Saudi Air Force manuals. It also looked for any previous attempts to modify or develop the process to make it easier or safer. In addition, it determined if there are any Air Force regulations that limit or prevent any improvements to the maintenance process.

The information the research collected provided the basic information that the researcher needed to start the journey of improving the AC-130 maintenance process. The information was enough to see if there were any administration obstacles to the process improvement. Through this information, it was possible to know how the AC-130 maintenance process should be done theoretically based on the manuals in order to compare it later with what is done practically in the field. The questions are:

Q1- In the AC-130 maintenance process, has there been any current or previous attempts to apply Lean?

(If yes, more detail information is required) If no, then why not as well. Maybe not enough time or resources to make an attempt?

Q2- Has there been any other kind of management attempts to improve the AC-130 maintenance process?

(If yes, more detail information is required) If no, then why not as well. Maybe not enough time or resources to make an attempt?

Q3- Are there any Royal Saudi Air Force Manuals that show how the AC-130 maintenance process should perform?

(If yes, more detail information is required)

Q4- Are there any Royal Saudi Air Force regulations that prevent improving the AC-130 maintenance process?

(If yes, more detail information is required)

Q5- Do you think there are wastes in AC-130 maintenance process?

(If yes or no, more detail information is required)

Q6- Do you think there is room for improvement in the AC-130 maintenance process and if yes, then what can be addressed?

See Appendix (A) for the feedback answers for Questionnaire number 1.

Questionnaire No.2

Questionnaire number 2 looked for any information that is related to the Lean process, such as wasted steps that can be improved. It targets the workers at the bases who are in direct contact with the AC-130 maintenance process and could explain the process. Their experience in maintenance will provide this research with valuable information. Their answers for questionnaire number 2 guided the researcher to where and how Lean could be applied.

Questionnaire number 2 was also given to the AC-130 maintenance squadron staff. Questionnaire number 2 was also given to five maintenance squadron individuals who are working in the Aircraft Generation Flight and they are:

1- The Aircraft Generation Flight Commander

2- The Aircraft Generation Flight Superintendent

3- The Aircraft Generation Flight Cell Chief

4- The Aircraft Generation Flight Controller

5- The Aircraft Generation Flight Material individual

The goal of contacting these people in different management levels and in different sections or departments was to make sure that the researcher was aware of all steps currently being practiced in the field and to ensure that if any of the staff who has been questioned overlooked a step, other Air Force members would mention it.

Questionnaire number 2 was developed to collect data that would help to decide if Lean is appropriate for the AC-130 maintenance process. The questions are:

Q1- How many years did you work in the maintenance squadron?

Q2- What is your current job description?

Q3- How many years or months have you worked in your current job?

Q4- How many hours are you supposed to work weekly and how much over time do you work?

Q5- Describe in steps how the AC-130 general maintenance process performs?

Q6- What areas can be improved upon and what resources/changes need to occur for the change to take effect?

Q7-Do you think the AC-130 maintenance process has a lot of wasted time or unnecessary movement?

Q8-Can you identify unnecessary or inefficient steps in the AC-130 maintenance process?

Q9-What changes would you suggest to the AC-130 maintenance process?

Q10-What are the obstacles that you face that prevent you from changing the AC-130 maintenance process?

See Appendix (B) for the feedback answers for Questionnaire number 2.

Questionnaire No.3

Questionnaire number 3 was developed to determine quantitative information pertinent to the AC-130 maintenance process to include average daily work hours and average time in performing aspects of some particular AC-130 maintenance process. This data aided the researcher in drawing some figures to study the current AC-130 maintenance situation. The questions are:

Q1-What are the average daily work hours to perform the AC-130 maintenance process in the last three months?

Q2-What is the average time for changing a main landing gear tire in the last three months?

Q3-What is the average time for changing the antenna in the last three months?

Q4-What is the average time for receiving a part from the supply in the last three months?

Q5-What is the average refueling time in the last three months?

See Appendix (C) for the feedback answers for Questionnaire number 3.

Questionnaire No.4

Questionnaire number 4 was developed to collect some information about how far location separations were and how long communication and waiting time takes in both the standard and the worst cases to measure the reduction that we can make in both cases.

Q1-What is the distance between the flight line and shops?

Q2-What is the standard communication time for each maintenance process?

Q3-What is the worst case communication time for each maintenance process?

Q4-What is the time required in each maintenance process?

Q5-What is the worst case time required in each maintenance process?

Q6-What is the average time required in each maintenance process?

See Appendix (D) for the feedback answers for Questionnaire number 4.

Questionnaire No.5

Lean, in this instance, is all about the immediate customer's desires. The AC-130 maintenance process is about making the AC-130 aircraft fully mission ready for their immediate customers, the pilots. Some pilots were interviewed to see what they are looking for as customers of the AC-130 maintenance process. Also, they were asked if they wanted to help improve the maintenance process and how they could help. All the information was collected from interviewing the customers using questionnaire number 5. The questions are:

Q1-When do pilots discover maintenance issues?

Q2-When do pilots debrief?

Q3-What is the time between discoveries and debrief?

Q4-What is the quality of that communication?

Q5-Can that time from discovery to debrief be shortened?

See Appendix (E) for the feedback answers for Questionnaire number 5.

Chapter Summary:

Questionnaires are a cost-effective, simple and quick way to gather data that comes straight from the sources. This research method has been used for decades to gather data but it comes with its own complications .They are complex instruments and, if badly designed, can be misleading.

Questionnaires are effective mechanisms for efficient collection of information. Some advantages of questionnaires are:

1. They can address a large number of issues and questions of concern in a relatively efficient way, with the possibility of a high response rate.

2. They permit respondents time to consider their responses carefully without interference.

3. Cost. It is possible to provide questionnaires to large numbers of people simultaneously.

Five questionnaires were developed and given to different participants to share their own ideas; the results are discussed and analyzed in next chapter.

IV. Results and Analysis

Overview

This chapter aims to stage the results of this research, obtained after applying the methodology proposed, to answer the research question.

The following information was collected by the researcher from the questionnaires that were sent to the Royal Saudi Air Force. The first questionnaire was answered by 30 individuals out of 120 (a 25% response rate) from the Aircraft Maintenance Administration (AC-130 Department). The second questionnaire was given to the Aircraft Generation Flight staff where 60 employees out of more than 1200 people (5% response rate) answered this questionnaire. The third questionnaire provided information from the AC-130 Analysis Department where around 40 people work (100% response rate). The fourth questionnaire provided information about how far location separations were and how long communication and waiting times take in both the standard and the worst cases. The fifth questionnaire was answered by 17 pilots (a 57% response rate) to get the customer's point of view.

It is important to boost questionnaire response rates to increase the validity and usefulness of the results. However, the response rates for the second questionnaire was low (this was because of the high wok intensity) which can limit the usefulness of the results.

Questionnaires were sent to the Royal Saudi Air Force and one of the officers on site acted as the point of contact and the research coordinator. After collecting the raw responses to the questionnaires using Microsoft Excel 2010, all the data and information was described and summarized in bullet lists and charts to make it easier to understand. This process made it easier to understand what kind of information could help in improving the AC-130 maintenance process.

Questionnaire No. 1

The following information was collected from the questionnaire responses:

• Lean has not been applied to the AC-130 Maintenance Process at all in the past.

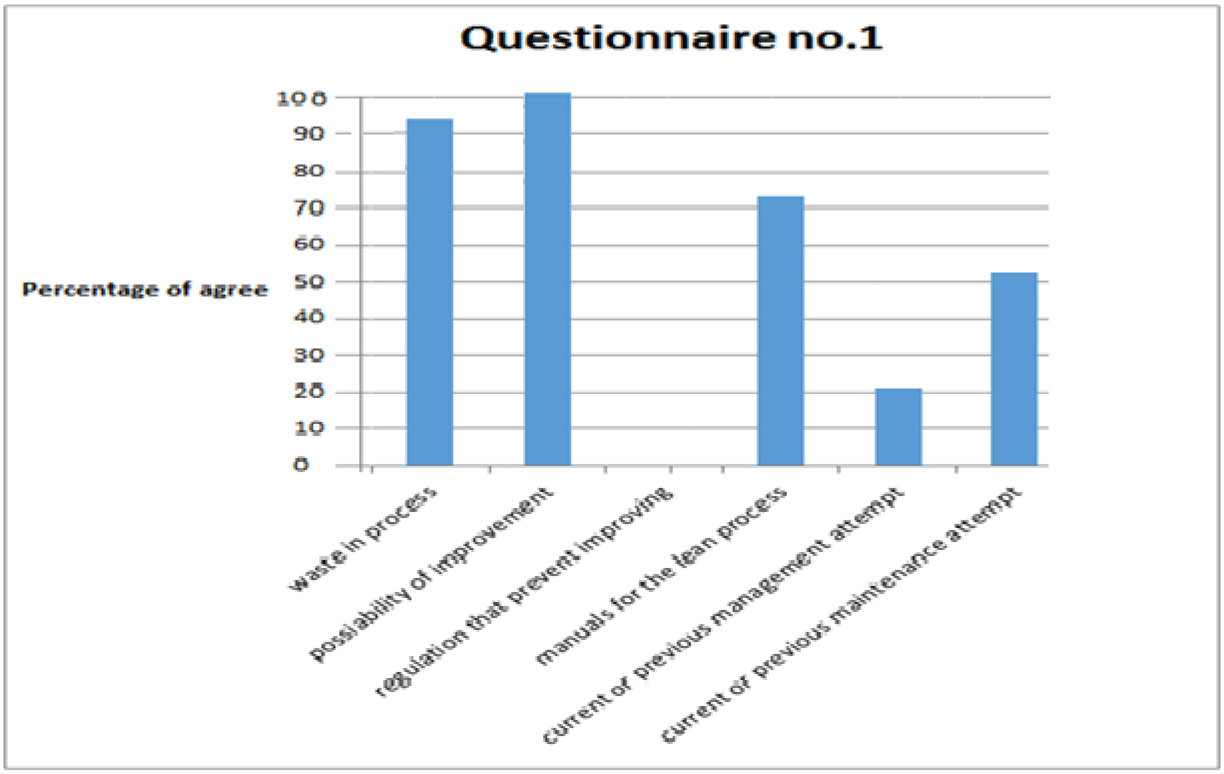

Figure 4. Overall Responses for Questionnaire 1

• The Royal Saudi Air Force is still trying to enhance and enforce Total Qualities Management in the maintenance process.

• People provided different answers about if there are Royal Saudi Air Force books or manuals that show how the AC-130 maintenance process should be done. This indicates that some respondents were confused or didn't understand what the question was asking for or maybe they did not have full knowledge of what is in the manuals.

• The Royal Saudi Air Force has no restrictions or regulations that prevent or limit the developing of the AC-130 Maintenance process.

• Individuals in the Royal Saudi Air Force HQ believe that AC-130 maintenance process can be developed. Most of them named Team Work as a solution.

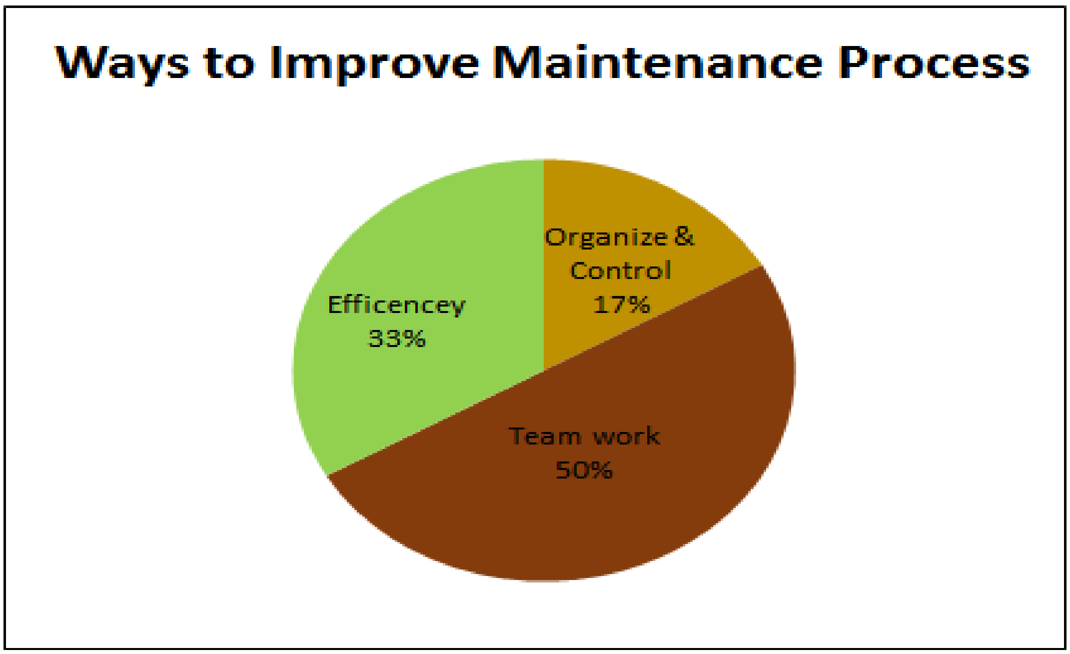

Figure 5. Ways to improve maintenance process

•Individuals in the Royal Saudi Air Force HQ agreed that there is a lot of waste in AC-130 Maintenance Process steps. The following reasons were cited in their responses:

There is no concentration while performing the job, there is no team work, there is no plan before performing the job, time is not enough to do the job correctly from the first time and some people don't care because there are no disciplinary actions taken.

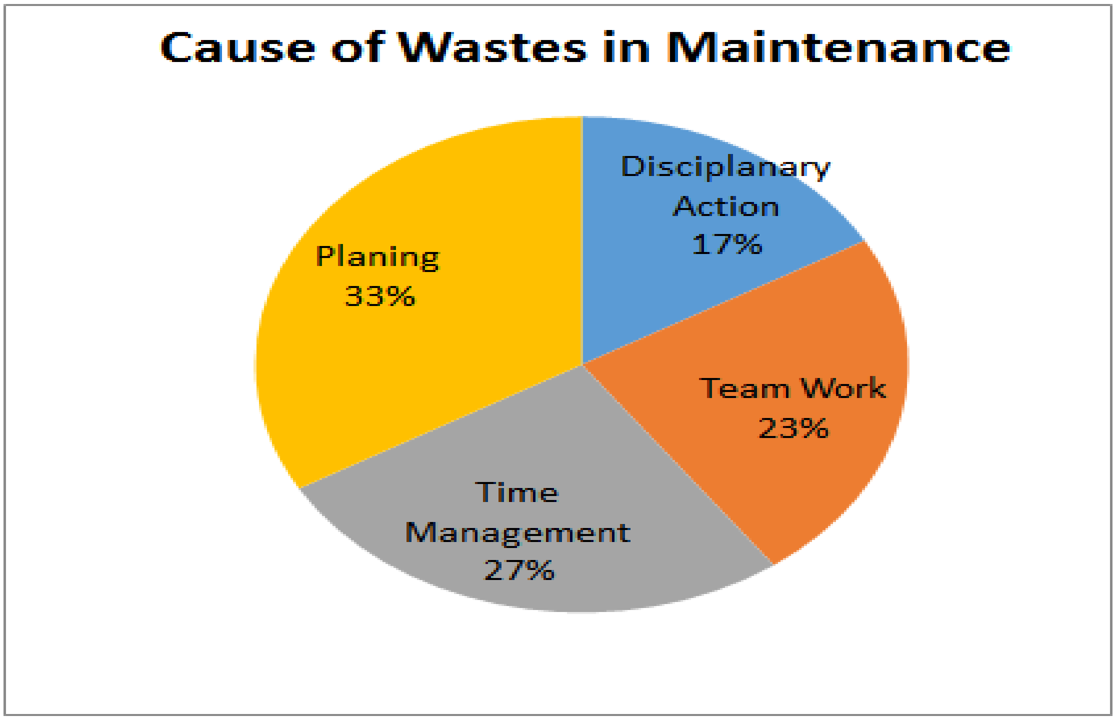

Figure 6. Causes of waste in maintenance

Questionnaire No. 2

The following information was collected from the second questionnaire responses:

• People who answered questionnaire number 2 had 5 to 25 years of experience working in Maintenance. They had different jobs and they were working at different levels.

• Participants named shortage of manpower, supply problems and waiting for support, tools, transportation and parts as solution to improve AC-130 maintenance process.

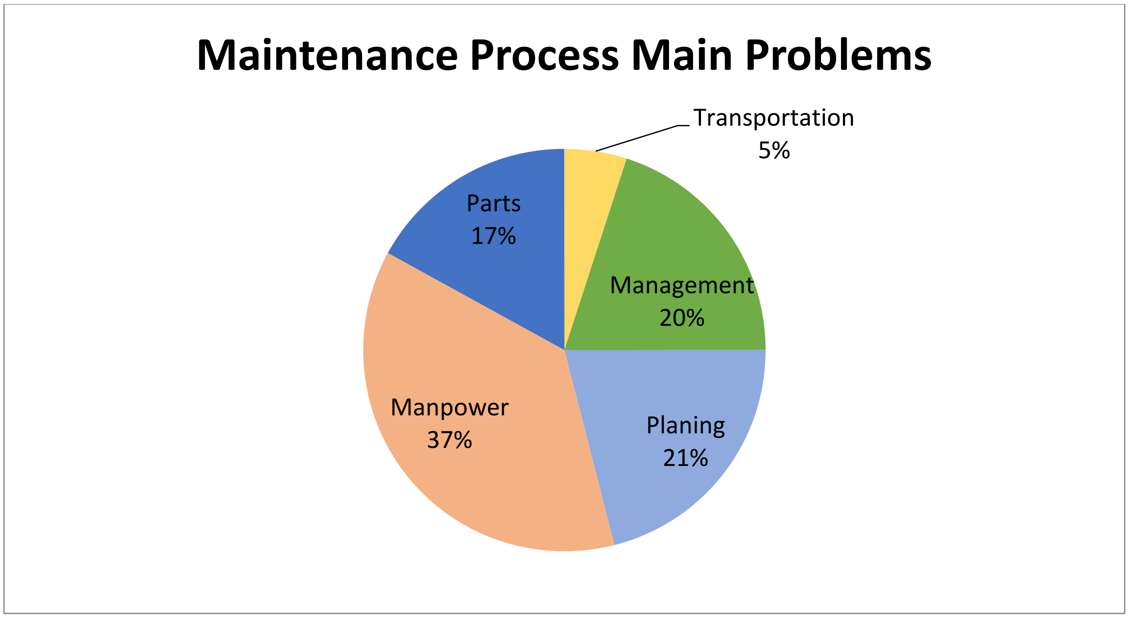

Figure 7. Main problems in the process

• Most of AC-130 Aircraft Generation Flight individuals who answered the survey thought there was no step that could be considered as a waste in the AC-130 maintenance process. Some of them preferred to leave the AC-130 maintenance process the current way to ensure work quality and safety.

•When the AC-130 Aircraft Generation Flight individuals answered what they wanted to develop in the AC-130 maintenance process, their answers were: Organization, planning, cleaning and all of them agreed on time.

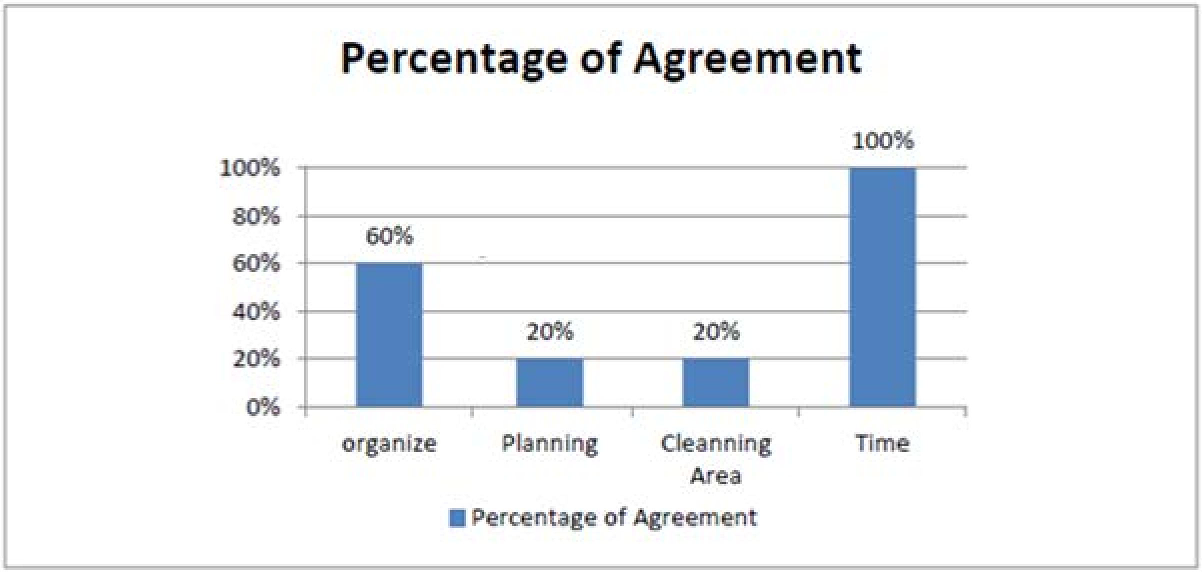

Figure 8. Questionnaire No.2 Responses

The AC-130 Aircraft Generation Flight individuals thought the rules and regulations of the Royal Saudi Air Force were the main reason that prevented them from developing their jobs relating to the AC-130 Maintenance Process.

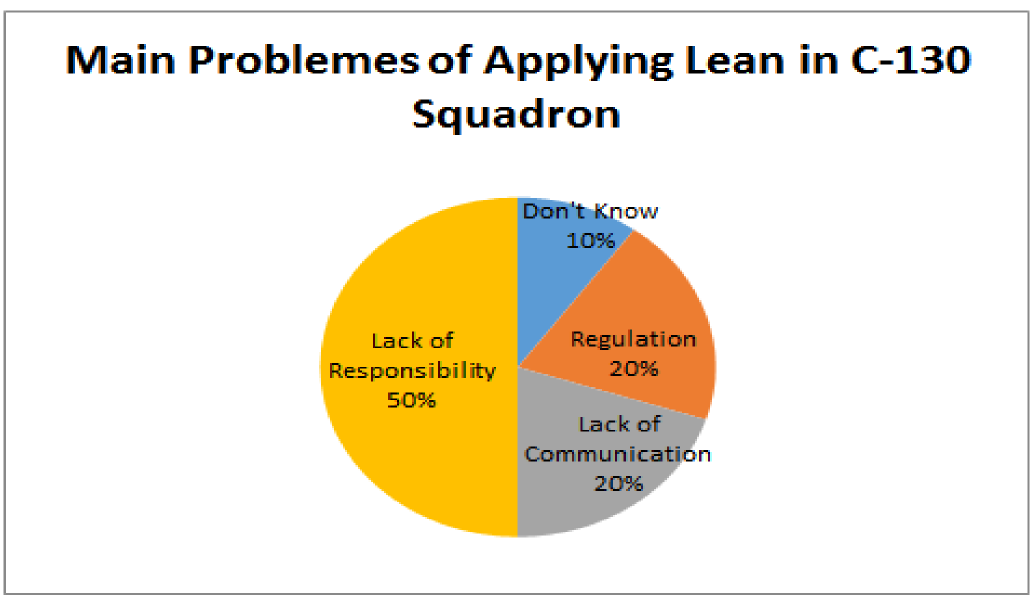

Figure 9. Main problems of applying Lean

The AC-130 Aircraft control staff individuals think that the work order management system is the main reason that prevents them from developing their jobs relating to the AC-130 Maintenance Process. They give examples of lost opportunities to achieve Lean performance through a work order management system that includes:

• Parts and/or labor charged to an incorrect work order number; the extreme example of this is that a work order remains open for days or weeks and becomes a “standing work order” that includes several separate tasks.

• Entering incorrect actual time required, often evident by the actual time being identical to the estimated time in most cases.

• Ignoring the recording of small time increments with the assumption that they are not important.

• Performing maintenance without a work order to document activity.

• Not completing work order in a timely manner, and relying on memory to recall the important details.

• Failure to record the “as-found” condition of equipment (this misses a huge opportunity to provide important feedback to the maintenance program that enables continued improvement of maintenance intervals).

The three items below describe what information is desirable to obtain from the maintenance staff that is actually performing the work:

• A description of the “as-found” condition

• Steps or a process used to perform maintenance; this could refer to any planning documents that are part of the work package but state just the exceptions or suggested improvements to the plan.

• Accurate feedback on time required, safety issues, parts required, and all materials required, to compare with estimates if available. When a work order management system is first deployed, it may be obvious if data entered by maintenance staff is inaccurate or incomplete. Eventually, periodic audits should be sufficient to assess compliance.

Questionnaire No. 3

AC-130 Analysis Department answered questionnaire no 3. After reviewing the responses, the researcher thought the received answers were not useful to the thesis and not accurate. The following information should be noted:

• The time to change parts is not constant. Easy jobs that usually require 30 minutes to accomplish might take 4 hours or more in other cases.

• The answers were "it depends." It depends on priority, time and managers decisions.

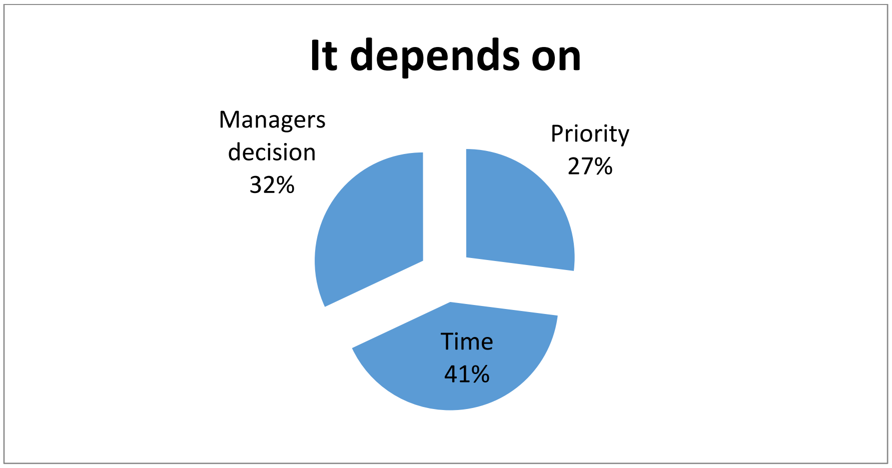

Figure 10. The time dependency

The researcher had to go back and ask the question, “why is the AC-130 maintenance squadron wasting this much time every day?”

To answer this question we need to know how the daily working hours are been managed. The average work hours for one month (18 December 2015 to 12 January 2016) shows a lot of overtime work compared to daily work hours. Weekends were excluded from the diagram. See Appendix (C) for the daily working hours in one month. A lot of time is wasted daily because of different reasons.

The first reason is changing shifts where some workers do not come to work on time which causes a lot of wasted time and delays the maintenance work. This will affect the plans and schedule for maintenance. There are other reasons for waiting time, for example, not responding fast, not understanding the defects, and not caring or not understanding the problems of wasting the time.

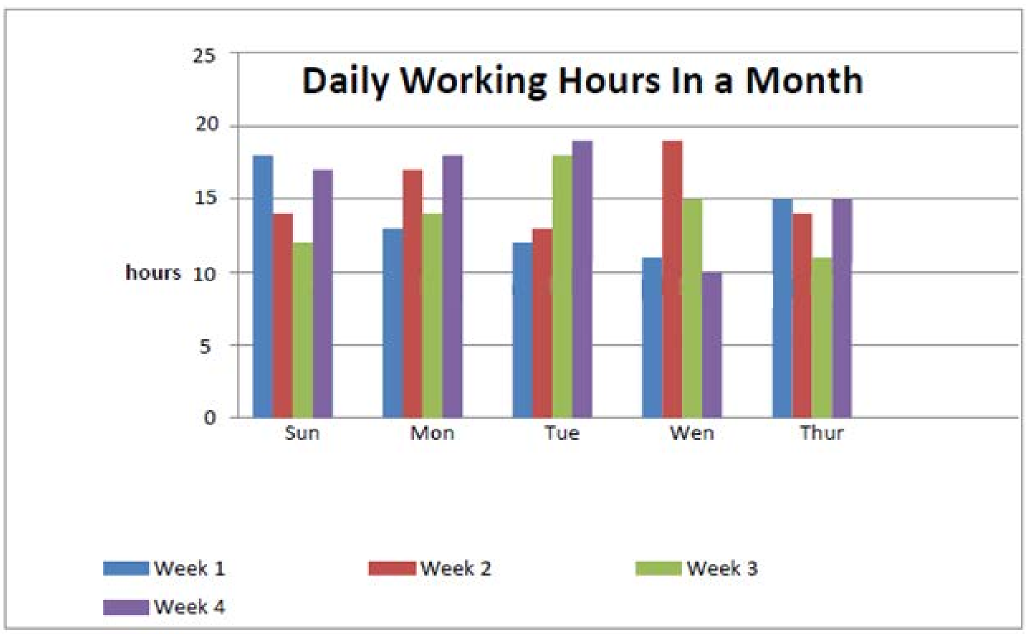

Figure 11. Working Hours

Table 1 shows the working time and shifts, this will help to understand how the shifts are managed and if we can improve the process by changing the arrangement of the shifts if possible

Table 1. Shifts working time

Shift	Working time
Morning shift	0730 – 1430
Gap shift	1430 – 1730
Swing shift	1730 – 0030
Night shift	0030 – 0730

The responses for the question “What are the other reasons for wasting time in the maintenance process?” were: changing shifts, transportation, waiting for parts and waiting for other shops to finish their work.

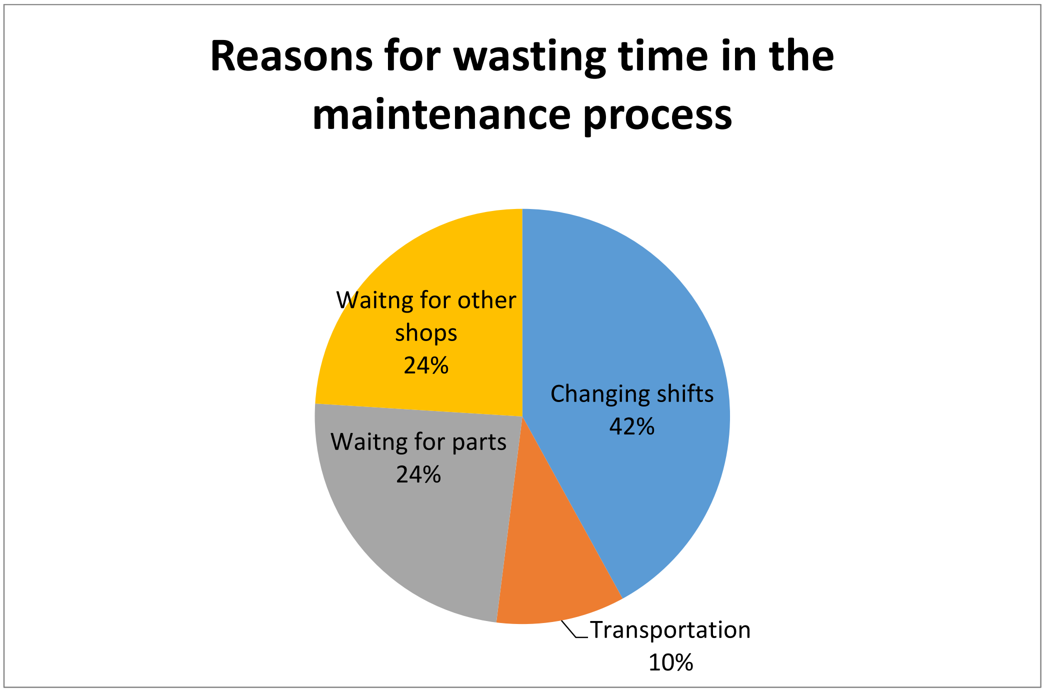

Figure 12. Reasons for wasting time in the process

Questionnaire No.4

Questionnaire number 4 shows how far location separations were and how long communication and waiting time take in both the standard and the worst cases. Communication and Waiting time is defined as the time between the call to the shop till the time the workers get to the aircraft.

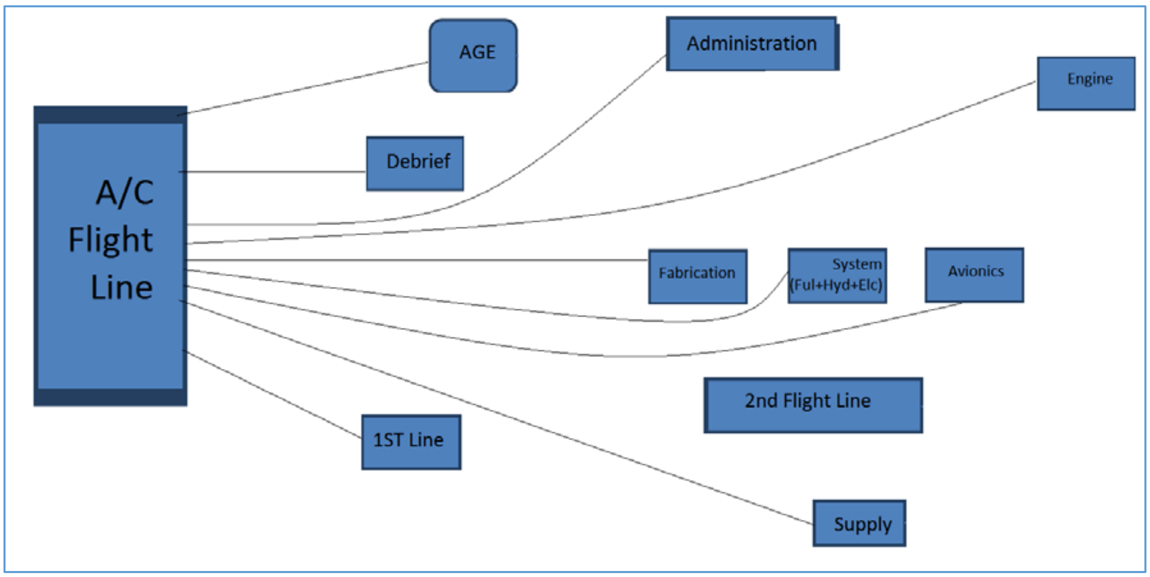

Figure 13. Locations of shops

Table 2 shows the distance between the shops.

Table 2. Distance from flight line

Department	Distance (m)
Debrief	400 m
Aviation Ground Equipment	300 m
First flight line	200 m
Fabrication	1200 m

System (fuel +hydrulic+electric)	1500 m
Avionics	1800 m
Engine	2500 m
Supply	3000 m

Table 3 shows communication and waiting time spend in C-130 maintenance process in standard and worst cases.

Table 3. Communication and Waiting time

Department	Communication and waiting time (minutes)	
	Standard	Worst
Debrief	10	50
Aviation Ground Equipment	5	80
First flight line	10	80
Other maintenance	15	80
Supply	20	240

Questionnaire No. 5

Questionnaire number 5 was answered by AC-130 Operation Squadron pilots. The following information was collected from the questionnaire answers:

Pilots discover maintenance issues before taking off, during the flight, and after landing. We couldn't use this question in our data because all feedbacks were the same. For the second question the pilots answered that they debrief as soon as the debrief room is ready.

The AC-130 pilots named the following as what they wanted from the Maintenance Squadron:

Not to accumulate work, finishing all jobs as soon as possible and maintain professionalism (they mean team work and good coordination with the maintenance staff).

All of AC-130 Maintenance process customers who answered the interview said yes, they want to improve the process and they will help if needed. They named many things that they think the C-130 maintenance squadron should focus on to improve the AC-130 Maintenance Process. These included: Team work, Raise workers morale, daily planning for all maintenance work, and reduce the waiting time.

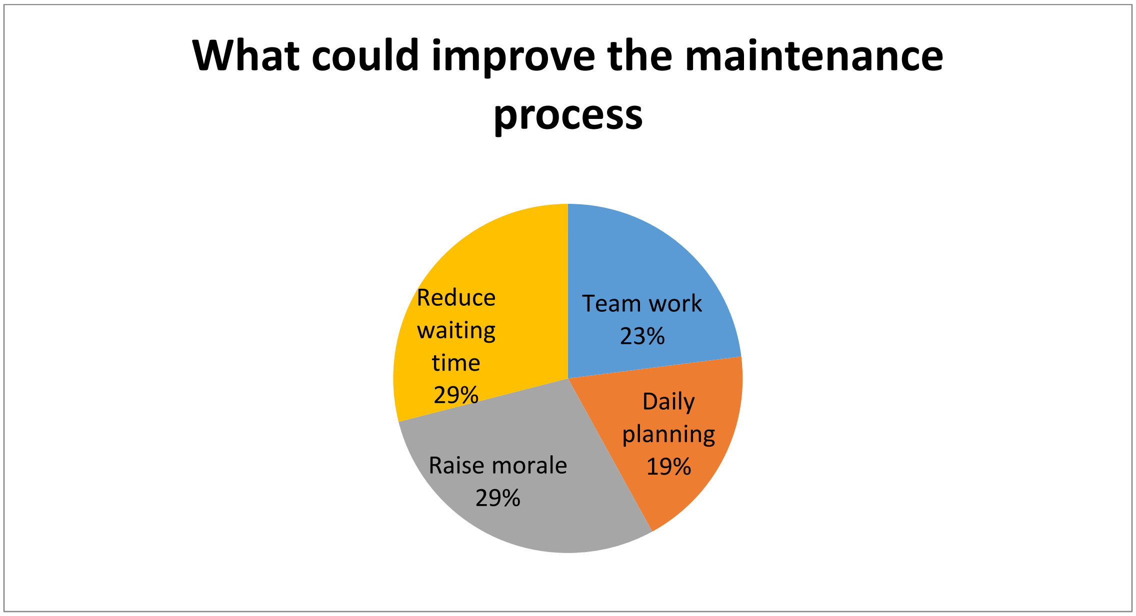

Figure 14. Improve the process

Process Flow

The fundamental concept of Lean maintenance is to reduce all resource needs (inputs) to the lowest possible level consistent with achieving the desired level of equipment reliability (output). To achieve this goal requires removing waste from all processes and activities (at any level). Waste is defined as any resource or activity related to the process that is not contributing value to the end “product.”

Lean can be effective within the context of any existing plant maintenance or reliability program. Lean maintenance is not typically implemented as a small number of large projects, but rather a large number of projects that each yields a small, sustained reduction in waste. The accumulation of these savings can be significant (Hesler, 2009).

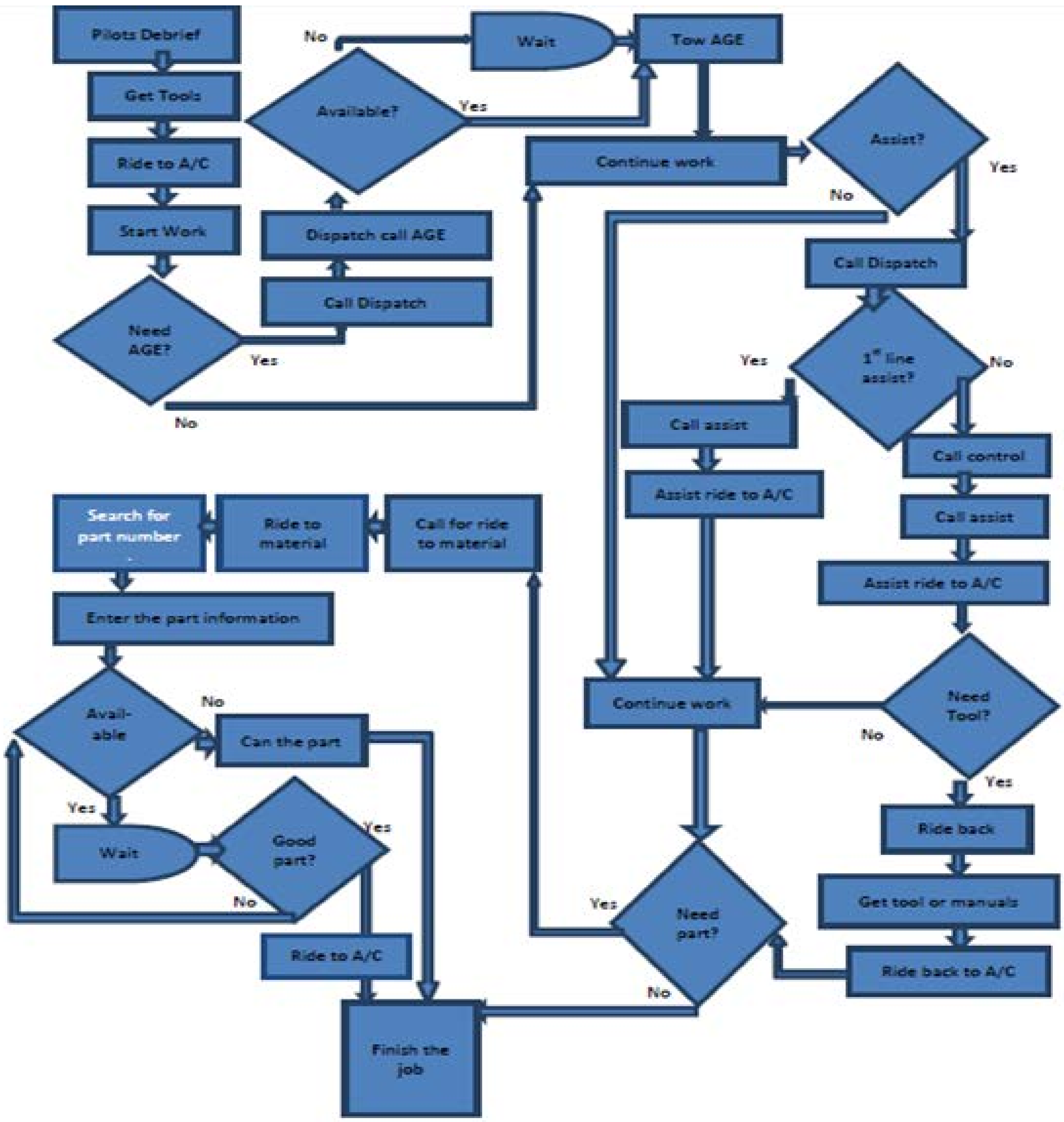

Figure 15. Current process map

Figure 15 is the current process map for the AC-130 maintenance process in the Royal Saudi Air Force (taken from the C-130 maintenance meeting, 2014), this will make it easy to understand the process and be able to eliminate the waste in the process and time. The following steps are the description of the AC-130 maintenance process steps:

1- Pilot and Technicians go to debrief room.

2- Technicians get the required tools (technicians have to travel using trucks), inspect them, provide a signature accepting that the tool is in good condition,

3- Technicians take ride to aircraft (time requirement depends on the distance from the shop to the location of the aircraft on the flight line).

4- If the aircraft needs Aviation Ground Equipment (AGE), the technician calls dispatch to request the AGE.

5- Dispatch calls AGE.

6- AGE tows the equipment if available to the aircraft. If not, the technician must wait until the next equipment is available.

7- The technician continues to work on tasks available with resources on hand.

8- If technician needs assistance, he calls dispatch.

a- If the assistance is from the first line technicians, Dispatch will call for assistance.

b- The first line technician assistant rides to the aircraft.

9- If the assistance is from some other department, dispatch calls Control.

a- Control calls the other department for assistance.

b- Other department technician rides to the aircraft to inspect the problem.

c- The assistant returns back to bring the tools they need.

d- The assistant gets their tools and manuals.

e- The assistant returns to the aircraft to begin working. If the aircraft needs a part the technicians call for a ride to the material office.

10- The technicians ride to the material office.

11- The material office personnel search for the part number.

12- The material office personnel call supply to order the part.

13- The supply personnel enter the part information.

a. If the part is available: the technician wait until the part arrives.

b. If the part is not available from supply, the part is taken from another aircraft.

c. Verify the part is the correct part and serviceable. If the part is not wrong or faulty, ask for another part.

14- The technician returns to the aircraft with the part.

15- Complete the work.

16- Finish the job.

Chapter Summary:

It is important to explain to the potential respondent why we believe they should answer the questions, doing so persuasively can improve response rate. The greatest enemy in survey research is the poor response rate. Clear and concise questionnaires can help get the best response. The response rate was good except for the second questionnaire because of the high intensity work they have. However, the sample obtained was enough to understand what employee think .We noticed that shop-floor level workers often understand the details of what is causing production slowdowns or missed delivery dates that are discussed in Squadron, and often have ideas on ways to make process improvements. If the lowest level employee was able to understand the principles of Lean, then continuous improvement is certainly possible in the AC-130 squadron. Value stream map of the processes was shown to identify and understand the processes. In the next chapter we will discuss the result of the questionnaire responses and the value stream map of the processes. Weaknesses in the current state process mapping will be analyzed and improved in the next chapter to obtain a better flow, faster and more efficiently.

V. Discussion

Overview

The goal was to use the Lean tool that, if effective, would greatly help managers to make decisions over the maintenance process to improve the efficiency.

Types of Waste Observed in the C-130 Maintenance Squadron

It is useful to describe the various categories of waste present in the C-130 maintenance processes. This report section will help to identify where waste may be present. There are five basic areas where Lean principles can be used to the C-130 maintenance squadron:

- Human resource management (Waiting time)
- Inventory management
- Quality management
- Information management (Communication)
- Distance

The following paragraphs provide more detail on the five waste categories.

Human Resource Management

This category is perhaps the most visible form of waste. It includes idle time spent by maintenance staff waiting for resources needed to complete the assigned maintenance task. This includes waiting for tools, supplies, instructions, another worker and safety equipment. A second form of waste in this category is unproductive time. This includes all non-idle time spent on the maintenance task. For example, the time spent mobilizing all resources at the specific location where the maintenance will be performed. A third form of waste is associated with non-optimum utilization of human resource skills. An example would be assigning maintenance personnel to tasks that are either above or below their skill levels.

Inventory Management

Another very common source of waste in maintenance involves the inability of the supply inventory management system to provide needed spare parts, materials, and supplies in time to permit the task to be undertaken as scheduled. Poor inventory management involves a number of waste-producing aspects. There is an ongoing struggle between the tendency to overstock (the preference of the maintenance staff) and the tendency to under stock (the preference of the accounting staff). Ability to predict demand for parts and supplies (forecasting), based partly on accurate historical data (work orders), is key to approaching the goal of “just in time” inventory management.

Quality Management

Poor quality of maintenance contributes to rework, which is an obvious form of waste. It would be very wasteful to have to repeat these maintenance steps due to an error that can only be corrected following a lengthy process. In these cases, the consequences of rework are very significant.

Within the C-130 maintenance squadron, quality must be achieved through continual process improvements, rather than relying solely on post-job inspections. Some waste is accrued by creating the maintenance error, even if it is discovered prior to returning the equipment to service.

Information Management

Poor or inefficient management of information critical to maintenance tasks is another category of waste. Essentially, waste is introduced by not using the computer system to its potential, or by entering incorrect data. Lost opportunities to reduce waste through continual improvement programs occur when the computer system database is not used to:

a) Assist inventory management.

b) Track actual labor against estimates.

c) Identify maintenance basis violations.

Distance

This category is directly affecting other sources of wastes. This includes the distance between the aircraft and the other departments. A second form of waste in this category is the distance between the management and the flight line which makes it hard to manage and keep updated on status changes to aircraft availability.

Identify the waste in the process

We will try to identify the four main possible wastes in the process. We identify the process flow by dividing the steps into valued, non-valued and waste steps. We colored the process flow to make it easier to identify where these four wastes fell. After coloring the process flow, the four areas are clearly circled in Figure 16.

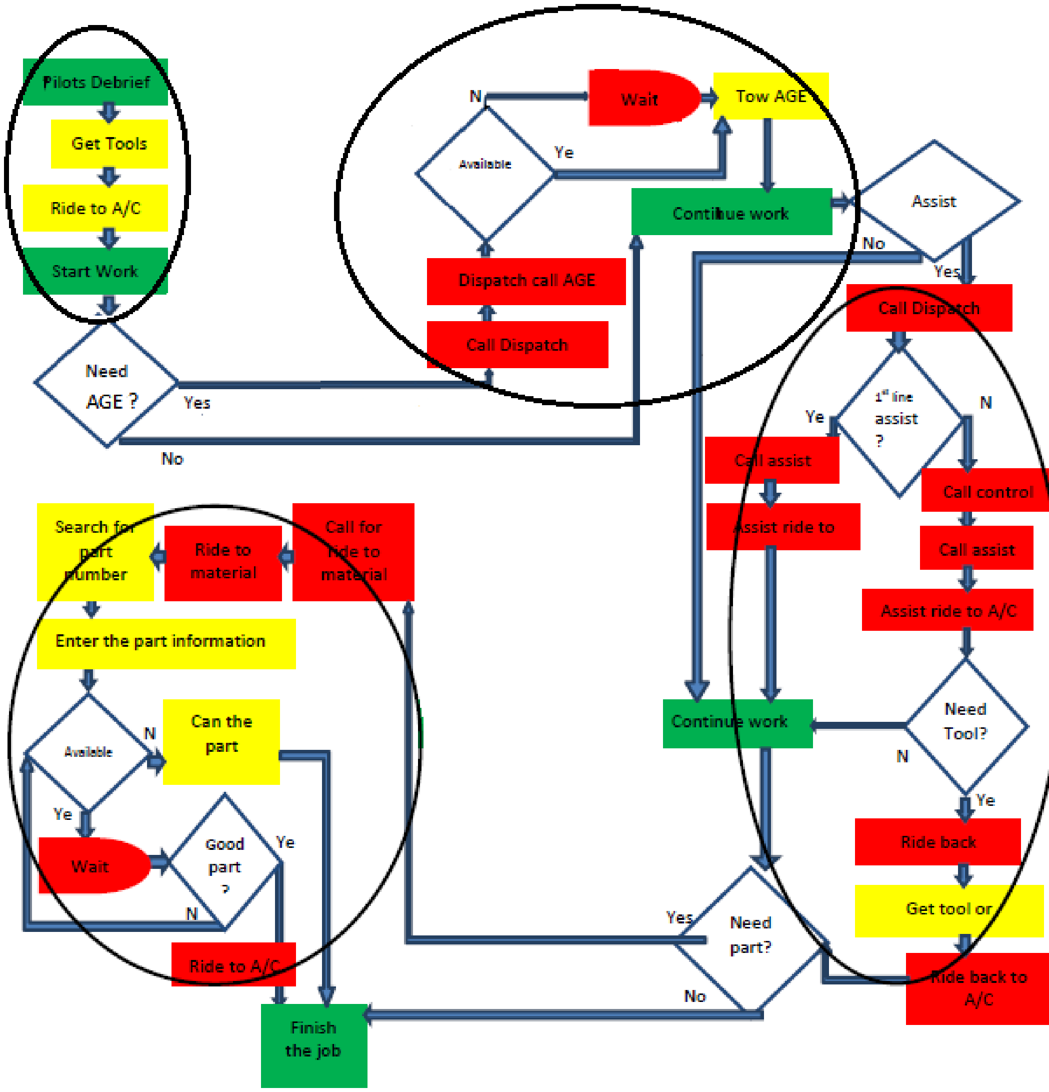

Figure 16. Identify the waste in the process

The following figures show C-130 maintenance process flow with numerical information for communication and waiting time and distance in both worst and standard cases.

A1: The time required for the pilot to debrief could be 10-50 minutes

A2: The Aviation Ground Equipment communication and waiting takes 5-80 minutes

A3: a- Assistance from the first line: 10-80 minutes

b- Assistance from other maintenance department: 15-80 minutes

A4: Supply communication and waiting time takes 20-240 minutes

The following is a description of the distance samples:

C1: Distance between debrief and aircraft area is 400 m.

C2: Distance between the Aviation Ground Equipment area and aircraft area is 300 m.

C3: Distance between other maintenance departments and 1st line aircraft is 1.2-2.5 km.

C4: Distance between supply and 1st line aircraft is 3 km.

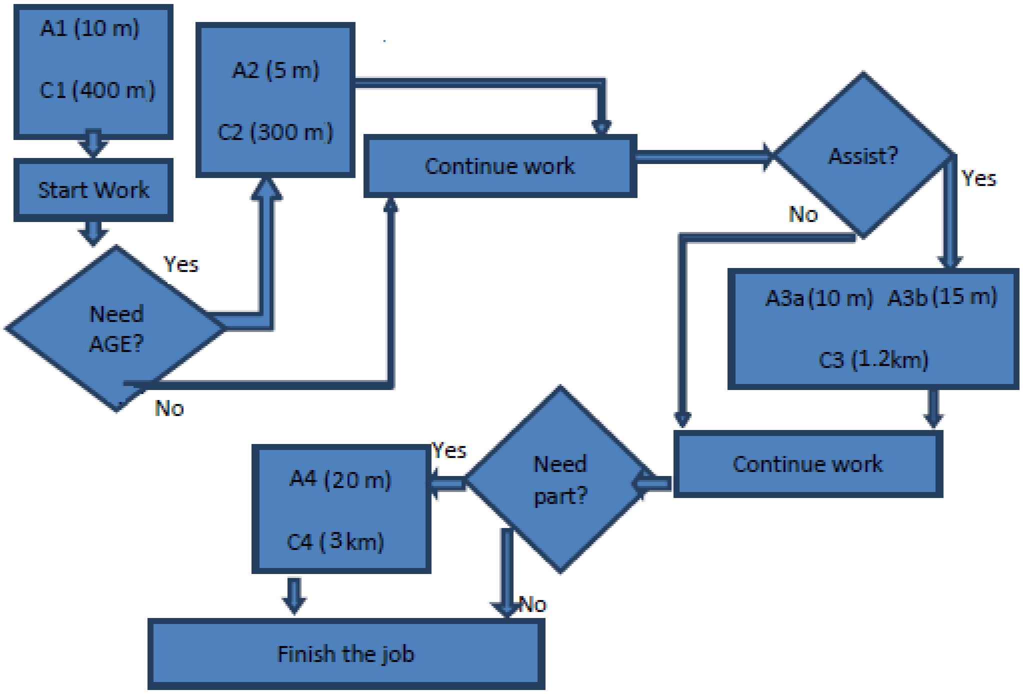

Figure 17. Maintenance flow for standard case

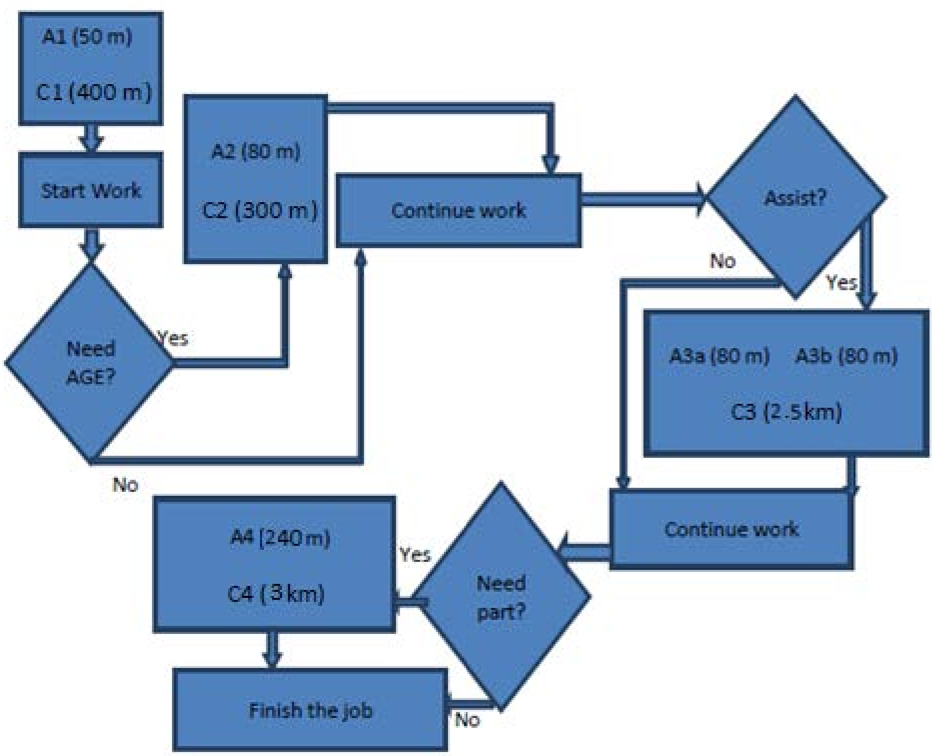

Figure 18. Maintenance flow for worst case

Maintenance Process Elements Affected by Lean Implementation

The RSAF has to think beyond the traditional ways of accomplishing the work and look for optimal ways of removing waste. We need to look across the organization at every process that impacted the way staff performed maintenance on the C-130. Instead of looking to improve individual sub-processes, the team needs to look at process interactions, including requirements, infrastructure, materiel support, and information technology.

What changes should we expect by implementing Lean?

1. More work will be accomplished in fewer hours

2. Decrease knowledge barriers of aircraft conditions that previously resulted in lost availability

3. Mechanic-centered maintenance process with maximum use of kitting may result in a reduction in lost time by having one tool room near the fight line.

4. Change the supply chain management and integration to have less waste in materials, tools, movements and time.

Reducing waste in maintenance activities can be addressed at a number of levels and across a range of maintenance process elements. Below are eleven key process areas with brief explanations of where waste can be reduced in the C-130 maintenance squadron (Levitt, 2006).

1. Work Planning: Effective planning reduces one of the major sources of waste in maintenance. A detailed work plan identifies all resources needed, enabling the scheduler to coordinate whereas poor work planning can contribute to maintenance errors.

2. Work Scheduling: The scheduler matches resources to tasks, coordinates with operations, prioritizes work for the optimum interests of the squadron, and projects the need for resources to handle unplanned corrective maintenance.

3. Work Order Management System: Written work orders, managed through a computer system, eliminate waste due to poorly communicated maintenance instructions. In addition, the computer system can be an effective feedback and archival tool. Effective training of maintenance staff on the computer system will reduce waste associated with input and retrieval of information.

4. Inventory Management: In an ideal maintenance program, spare parts and stores are available "just in time" for their required use. Poor inventory management introduces waste by creating excessive unused stock, or the opposite situation of unavailability of material when needed for emergency maintenance tasks. Waste also results from a poorly managed storeroom that is unable to locate and efficiently retrieve material when needed by maintenance staff.

5. Predictive/Preventive Maintenance: Predictive maintenance will reduce the waste associated with overly conservative time-based maintenance. It will also reduce the waste associated with unplanned corrective maintenance resulting from failures that could have been predicted through condition monitoring.

6. Corrective Maintenance: A certain amount of corrective maintenance will be necessary even in a Lean organization. Examining an organization's processes for executing corrective maintenance can highlight Lean opportunities. Lean in this situation can be accomplished by having standardized maintenance plans on file; materials, equipment, and supplies available; and dedicated tool sets devoted to correcting the most common write-ups.

7. Engineering: Engineering staff must take the lead in efficient application of the maintenance process for establishing the maintenance basis. Knowledge of failure modes and effects is critical to optimizing the maintenance program, and this requires engineering input. Engineering plays a key role in performing root cause analyses, which reduce wasteful repeat failures. Engineering can improve equipment design to eliminate some failure modes, making the related maintenance activity unnecessary.

8. Training. Lean can be introduced to the maintenance organization through cross-training of maintenance staff. Cross-training allows flexibility in planning and subsequently reduced idle time associated with waiting for availability of specific expertise. Cross-training improves problem-solving skills and could potentially result in reduced staffing needs. In addition, the training process itself could be made Lean through the use of worker task performance evaluations to pinpoint skill deficiencies and deliver only specific areas of training needs.

9. Planning: An effective planning effort identifies and resolves all issues or problems in advance of scheduling the maintenance activity, thus avoiding the idle time associated with waiting to resolve those issues on the day the task is scheduled to be performed. The most common issues that planners seek to resolve in advance are the following:

• Availability of parts and materials and preparation of a tools and parts list

• Availability of any personal protection equipment

• Assembly of a work package and clear instructions

• Clearance with operations to allow access to the Aircraft and release of equipment

• Identify any safety considerations

• Most importantly, communicate with all involved in the task

10. Scheduling: If the planning is completed properly and the work program is established, scheduling becomes a matter of selecting ready backlog and scheduled activity for the week. One important Lean role for the scheduler involves the responsibility for continuous improvement. It is therefore valuable for each weekly coordination meeting to address the performance of the previous week.

11. Communication: The work order management system is the conduit for an essential two-way communication. In one direction, instructions are given to the maintenance worker. In the other direction, findings and actual resources required to complete the task are fed back to the planner. This process facilitates one of the most important elements of continuous improvement in plant maintenance.

Improving the process

To improve the process and make the reduction in C-130 maintenance process we recommend the Royal Saudi Air Force to eliminate time that been wasted in waiting and unnecessary communication. Another major thing Royal Saudi Air Force should consider is to shorten the distance between maintenance shops, supply and Aviation Ground Equipment. Figure 13 shows distance between supply, other maintenance departments, Aviation Ground Equipment and Aircraft Generation Flight. Figures 19 and 20 show the new and improved F-15 Maintenance Process.

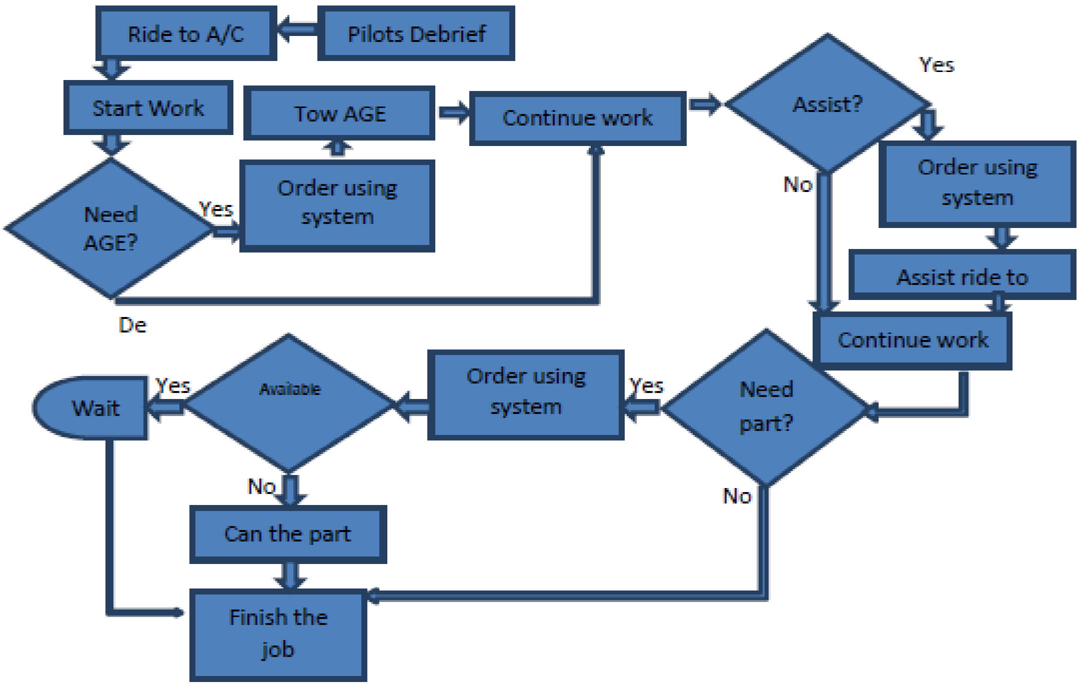

Figure 19. Recommended process

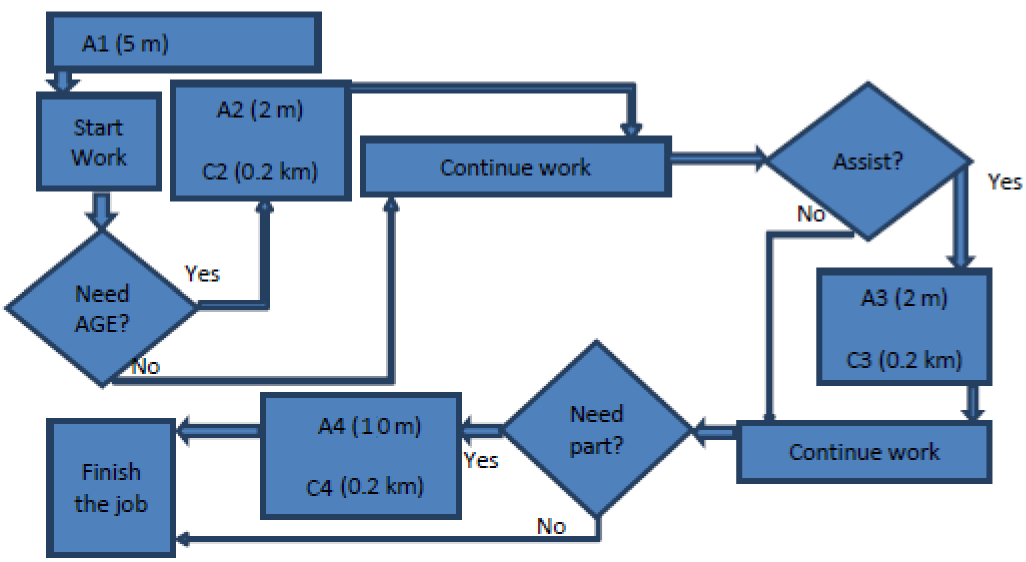

Figure 20. Recommended process in numbers

The process can be improved by reducing distance. For Aviation Ground Equipment, the distance should be 200 meter in maximum (there are unused offices by the flight line shown in green in figure 21). There is no need to be that far if their main purpose is to help the aircraft get fixed. Reducing the distance will surely help reducing the time wasted in movement. The supply also should have closer place than there warehouse. In case of intermediate maintenance departments assist, having their technicians working in the Aircraft Generation Flight area will eliminate the distance completely.

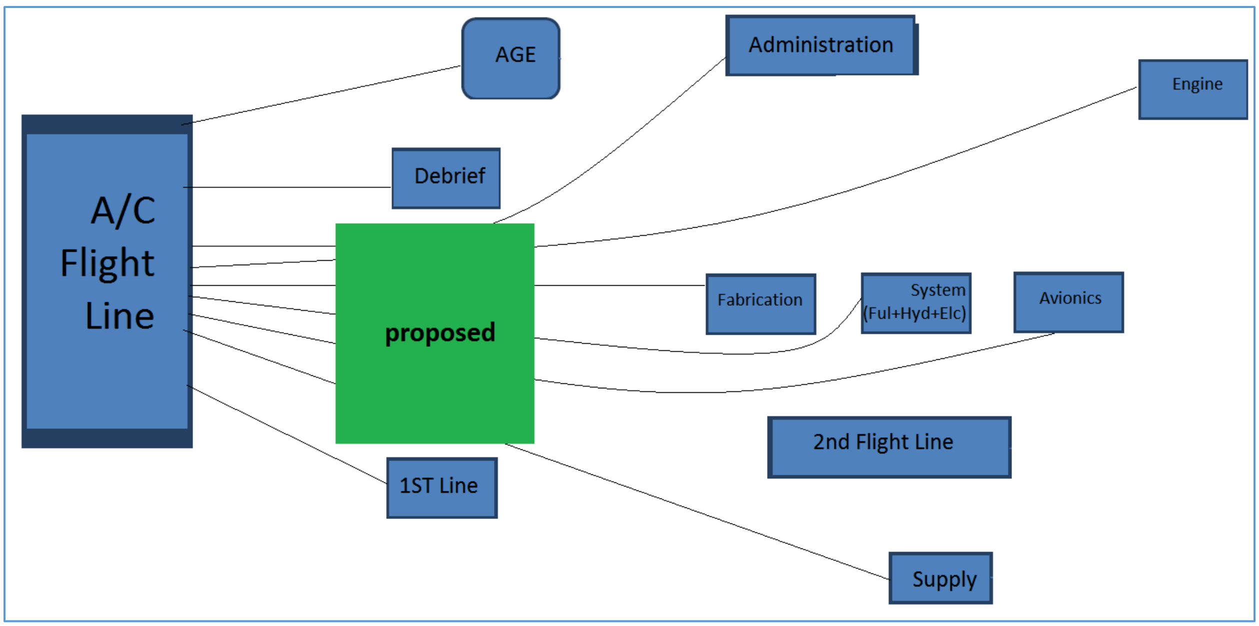

Figure 21. Recommended location

Table 4 shows the reduction when Lean is implemented:

Table 4. Reduction when Lean is implemented for distance

Department	Distance (m)	Proposed (m)	Reduction
Debrief	400 m	200 m	50%
Aviation Ground Equipment	300 m	200 m	33%
First flight line	200 m	200 m	0%
Fabrication	1200 m	200 m	83%
System (fuel +hydrulic+electric)	1500 m	200 m	86%
Avionics	1800 m	200 m	89%
Engine	2500 m	200 m	92%
Supply	3000 m	200 m	93%

Communication and Waiting time is another deep issue in the C-130 maintenance processes. It can be fixed by using many solutions. One solution is to use available technology i.e. computers that any technician can access and ask for what he wants either ride, supply part or assistance and get the respond directly with estimating time.

After going through improvement by eliminating non-value adding process and time, the value is re-calculated to determine the time difference before and after the implementation of Lean. Based on the current mapping (Figure 15) and recommended mapping (Figure 19).

Table 5 shows times spend in communication in standard and worst cases comparing to propose that this thesis want to achieve.

Table 5. Reduction when Lean is implemented for time

Department	Communication and waiting time (minutes)		Propossed	Reduction	
	Standard	Worst		Standard	Worst
Debrief	10	50	5	50%	90%
Aviation Ground Equipment	5	80	2	60%	97%
First flight line	10	80	2	25%	97%
Other maintenance	15	80	2	15%	97%
Supply	20	240	10	50%	96%
Total Cycle Time	60	530	21	65%	96%

The cycle time before Lean is 60 minutes for the standard case and 530 minutes for the worst case, and cycle time after Lean is 21 minutes. There was a decrease of 65% in the standard case and 96% for the worst case. After the improvement process design has been applied, the process performance needs to be conducted to ensure that the process that occurs can indeed give a significant impact on the process performance, in accordance with the expected goal or target.

Challenges

The maintenance staff has difficulty visualizing how to implement Lean. The efforts of Lean will improve the maintenance "product" quality by lowering measurable process outputs such as amount of rework, number of maintenance-induced failures, and so on.

Below are some challenges areas of applying Lean:

1. The employee must feel part of the process

2. Management Strategies:

Traditional command and control must be replaced by delegation and empowerment. If a manager cannot get employees to create productive ideas, the manager must be willing to reassess his management style.

3. Training Staff:

Training is perhaps the largest cost component associated with a Lean initiative. Training is essential to success, and needs to involve all organizational levels. Training is the opportunity to communicate and align all staff on the initiative goals, as well as gaining proficiency with the basic tools of continuous improvement. There are many outside organizations that can provide this training on a contract basis. It may be more cost effective to consider a “train the trainer” approach, in which a limited number of staff (internal consultants) are trained extensively and are then given the task of providing specific training at various organizational levels. Training is an area that requires strong management commitment if the Lean initiative is to be successful. It is critical to train the entire organization, regardless of job function.

Tips for Starting

These are number of common ideas listed below for starting the Lean program (Aziz & Hafez, 2013) :

• Lean maintenance is not a replacement for a reliability improvement maintenance initiative. These are mature strategies that require their own focus to be successful. Lean should be implemented as a parallel effort. If the plant is struggling with equipment reliability or backlog, consider first getting these issues resolved prior to launching a Lean initiative.

• With Lean, start small and build on early, visible successes. Start the Lean initiative with an employee suggestion system.

• Visit peer companies that have launched Lean maintenance to obtain ideas and lessons learned.

• Obtain executive support with a clear understanding that the significant benefits may take 1–2 years rather than months to become evident and measurable.

• Strengthen the post-job feedback communication by maintenance workers to planners. If the computer is used to collect this input, set up a prompt requiring some feedback on areas for improvement.

• Create an employee suggestion program, but first ensure that all process elements and evaluation criteria are established beforehand.

• Ensure that there is effective communication, at all organizational levels, regarding the Lean program goals and expectations. Anticipate any employee concerns and be prepared with a response.

Chapter Summary:

In this chapter, Lean maintenance has been described starting with types of waste observed in the C-130 Maintenance Squadron, maintenance process elements affected by Lean implementation. This led to improving the process by reducing the cycle from 60 minutes for the standard case and 530 minutes for the worst case to 21 minutes after applying Lean. There was a decrease of 65% in the standard case and 96% for the worst case.

Challenges of applying Lean were discussed then finally gave tips for how to start implementing Lean. The next chapter will discuss the conclusion and recommendations for the thesis. Lean practices can apply to a number of maintenance process elements, ranging from work management to inventory management to root-cause analyses, just to name a few. The five key elements of any maintenance task that must be planned and scheduled are labor, tools/materials/parts, information/instructions/drawings, operations release, and any authorizations or permits required (Levitt, 2006).

VI. CONCLUSIONS

Overview

This report has provided a description of Lean maintenance from the perspective of the RSAF. Considering the potential to improve work quality, and improve the balance of preventive to corrective maintenance RSAF leadership will find this information to be a useful starting point.

The following conclusion summarizes the key topics and recommendations derived from this research.

Conclusion

Applying Lean to the C-130 maintenance squadron process suggests that time can be saved in the maintenance process, thus reducing the turnaround time needed to get aircraft ready to fly. Lean will make it possible to discover areas of process improvement.

So far, Lean has not been used in any C-130 maintenance process, and most of the individuals interviewed are not familiar with Lean. As the Royal Saudi Air Force continues trying to enhance the principles of total quality management and applying Lean, the quality of the maintenance process is likely to improve.

While gathering information for this thesis, it became clear that communication between the Royal Saudi Air Force Head Quarters and the bases can be improved. It was found that Head Quarters employees and some base level workers have a different understanding about the C-130 maintenance process regulations.

All interviewed individuals agreed that the process can be improved, and the majority of respondents agreed that there are unnecessary or wasteful steps that should be eliminated. Lean is designed to identify and eliminate these steps. Planning, sequencing and time management were given by the participants as possible solutions to improve the process and all of these proposals are used in Lean.

Lean considers waiting time and unnecessary or extra movement as waste that should be eliminated. From the gathered information, the C-130 maintenance process uses a lot of time in communication and waiting time, and distance. Lean challenges the traditional command and control style of management. Success is derived from empowering workers to identify and remove all forms of waste. Management's new role is to support cultural change by providing continued program support, process facilitation, training resources, and sustained executive endorsement. Lean does not conflict with existing equipment reliability initiatives. They share a common philosophy that waste is reduced when an organization moves toward more proactive and less reactive maintenance. Organizations adopting Lean should continue to emphasize development of their maintenance basis and improvement of their corrective action program.

This thesis investigated the C-130 maintenance process for two specific cases; worse case and standard case. This results show the amount of improvement is possible for each of these cases. These investigations show results when applying Lean to the C-130 maintenance process in the Royal Saudi Air Force in Table 4 and Table 5.

This thesis indicates that, theoretically, that the reduction in the F-15 maintenance process metrics could be 96% for the worst case and 65% for the standard case. This is a huge improvement in the process for both cases. If these gains can be realized, it will save a lot of the

Royal Saudi Air Force efforts in the C-130 maintenance process and increase the aircrafts' fight capability and readiness.

Employee training is a key element of Lean. First, program success is dependent on all employees acquiring a good understanding of basic Lean principles. Second, a limited number of in-house experts dedicated to Lean implementation will require more in-depth training. Third, cross-training of maintenance staff in multiple skill areas is a key element of Lean maintenance and should be encouraged.

Recommendations

• Start the Lean initiative with small-scale projects such as those in the area of work execution. Focus initially on employee engagement and culture change. Do not expect or demand an immediate return on investment.

• Promote "waste awareness" and "problem awareness" by employees. Back this up by instituting a formal employee suggestion program that includes incentives for participation and executive involvement in the award process (Hesler, 2009).

• Share successes as the Lean program begins to identify and reduce waste. Include recognition by management, regular reporting at executive briefings, and publicity in corporate newsletters (Hesler, 2009).

• Improve the process by eliminating time that is been wasted in waiting and extra communication. Another major thing is to shorten the distance between maintenance shops, supply and Aviation Ground Equipment (by utilizing the buildings by the flight line).

• Manage tool access to ensure that there is no wasted time spent either locating a missing tool or retrieving a tool.

Significance of This Research

This thesis is important to the Royal Saudi Air Force in several ways. It is good to recapitulate them to ensure their importance is not overlooked. One thing that makes this thesis so significant is that this thesis presents Lean as an idea for the Royal Saudi Air Force to adopt. Collected data shows that participants were unaware of Lean. Applying this thesis in the field can actually result in increasing the readiness of the aircraft. In addition, application of Lean will reduce the daily efforts and wasted resources, power and equipment.

Limitation of Research

This study is only a theoretical study. It has not yet been applied on the Royal Saudi Air Force C-130 maintenance process. It should also be noted that the thesis and data collection were obtained in both the USA and KSA.

Recommendations for Action

This thesis is theoretical research as mentioned earlier. Full support and cooperation from all related wings and departments should be ensured to provide this trial an optimal chance of success. The program should be provided with tools, equipment and manpower needed for a fair evaluation. If the trial program succeeds, it should be generalized to include other bases and other types of aircraft that the Royal Saudi Air Force uses. There is no problem including United State Air Force employees who are experts in applying Lean to the maintenance process as consultants to assist and/or supervise the trial and continued expansion of the process to other systems.

Recommendation for Future Research

Future research can take this thesis as a basis and apply it using ARENA or JMP to analyze the process and show how much improvement can be achieved by using Lean. Future research should also modify, extend, and improve on the assumptions and techniques made in this thesis or cover parts of Lean that this thesis did not address.

Appendix A. Questionnaire No. 1 Responses

	A	B	C	D	E	F	G	H	I	J	K	L
1						Questionnaire number 1						
2												
3		1		2		3		4	5		6	
4		No		No	time	No		No	Yes	efficencey while working	Yes	planing
5		Yes	whith no knoledge	Yes		Yes	not explained well	No	Yes	team work	Yes	time management
6		Yes	personal attempt	Yes		Yes	not explained well	No	Yes	team work	Yes	team work
7		Yes	in war time	Yes		Yes	not explained well	No	Yes	organize and control	Yes	time management
8		Yes	when airmen are been observed	Yes		Yes	not explained well	No	Yes	team work	Yes	planing
9		No		No	time	No		No	Yes	team work	Yes	disciplanary action
10		No		No	resourse	No		No	Yes	team work	Yes	team work
11		Yes	in war time	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	organize and control	Yes	planing
12		Yes	when airmen are been observed	Yes	personal attempt	Yes	not explained well	No	Yes	team work	Yes	time management
13		Yes	whith no knoledge	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	team work	Yes	disciplanary action
14		Yes	personal attempt	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	team work	Yes	team work
15		Yes	when airmen are been observed	Yes	personal attempt	Yes	not explained well	No	Yes	organize and control	No	airmen doing their best
16		Yes	whith no knoledge	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	team work	Yes	time management
17		No		No	time	No		No	Yes	efficencey while working	Yes	disciplanary action
18		Yes	when airmen are been observed	Yes	personal attempt	Yes		No	Yes	team work	Yes	planing
19		Yes	in war time	Yes	personal attempt	Yes	not explained well	No	Yes	team work	No	airmen doing their best
20		No		No	resourse	No		No	Yes	efficencey while working	Yes	planing
21		Yes	in war time	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	team work	Yes	planing
22		No		No	time	No		No	Yes	team work	Yes	time management
23		Yes	when airmen are been observed	Yes	personal attempt	Yes	not explained well	No	Yes	efficencey while working	Yes	team work
24		No		No	resourse	No		No	Yes	efficencey while working	Yes	disciplanary action
25		Yes	when airmen are been observed	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	efficencey while working	Yes	disciplanary action
26		Yes	when airmen are been observed	Yes	personal attempt	Yes	not explained well	No	Yes	team work	Yes	planing
27		No		No	time	No		No	Yes	organize and control	Yes	time management
28		Yes	in war time	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	team work	Yes	disciplanary action
29		No		No	resourse	No		No	Yes	efficencey while working	Yes	team work
30		Yes	personal attempt	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	team work	Yes	team work
31		Yes	in war time	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	efficencey while working	Yes	disciplanary action
32		No		No	time	No		No	Yes	team work	Yes	team work
33		Yes	in war time	Yes	personal attempt	Yes	airmen don't relise it	No	Yes	efficencey while working	Yes	time management

Appendix B. Questionnaire No. 2 Responses

	A	B	C	D	E	F	G	H	I	J	K
1						Questionnaire number 2					
2											
3		1	2	3	4	5	6	7	8	9	10
4		11	Flight Line	11	35	Detail	Management	No	Lack of responsibility	Time + Organize	Lack of responsibility
5		16	Flight Line	16	35	Detail	Planing	No	Lack of responsibility	Time + Organize	Lack of responsibility
6		7	Flight Line	7	35	Detail	Manpower	No	Lack of responsibility	Time + Organize	Lack of responsibility
7		10	Flight Line	10	35	Detail	Parts	Yes	Regulation	Time + Organize	Regulation
8		11	Flight Line	11	35	Detail	Manpower	Yes	Lack of communication	Time + Planing	Lack of communication
9		13	Flight Line	13	35	Detail	Parts	No	Regulation	Time + Cleaning Area	Regulation
10		12	Flight Line	12	35	Detail	Management	Yes	Lack of responsibility	Time + Planing	Lack of responsibility
11		25	Flight Line	25	35	Detail	Manpower	Yes	Lack of communication	Time + Organize	Lack of communication
12		20	Flight Line	20	35	Detail	Management	Yes	Regulation	Time + Organize	Regulation
13		12	Flight Line	12	35	Detail	Transportation	No	Lack of responsibility	Time + Organize	Lack of responsibility
14		5	Flight Line	5	35	Detail	Planing	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
15		6	Flight Line	6	35	Detail	Management	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
16		13	Flight Line	13	35	Detail	Manpower	Yes	Lack of communication	Time + Cleaning Area	Lack of communication
17		17	Avionics	17	35	Detail	Parts	Yes	Lack of communication	Time + Organize	Lack of communication
18		10	Avionics	10	35	Detail	Manpower	No	Regulation	Time + Planing	Regulation
19		19	Avionics	19	35	Detail	Manpower	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
20		20	Avionics	20	35	Detail	Management	Yes	Lack of responsibility	Time + Cleaning Area	Lack of responsibility
21		14	Avionics	14	35	Detail	Planing	Yes	Lack of communication	Time + Planing	Lack of communication
22		12	Avionics	12	35	Detail	Manpower	No	Lack of responsibility	Time + Organize	Lack of responsibility
23		8	Avionics	8	35	Detail	Parts	Yes	Regulation	Time + Cleaning Area	Regulation
24		18	Avionics	18	35	Detail	Planing	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
25		9	Avionics	9	35	Detail	Management	Yes	Lack of responsibility	Time + Planing	Lack of responsibility
26		10	Avionics	10	35	Detail	Parts	Yes	Don't Know	Time + Organize	Don't Know
27		13	Avionics	13	35	Detail	Manpower	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
28		12	Avionics	12	35	Detail	Transportation	No	Regulation	Time + Cleaning Area	Regulation
29		14	Fuel	14	35	Detail	Planing	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
30		23	Fuel	23	35	Detail	Manpower	Yes	Lack of communication	Time + Cleaning Area	Lack of communication
31		5	Fuel	5	35	Detail	Parts	Yes	Lack of responsibility	Time + Planing	Lack of responsibility
32		7	Fuel	7	35	Detail	Planing	Yes	Don't Know	Time + Organize	Don't Know
33		16	Fuel	16	35	Detail	Manpower	Yes	Lack of responsibility	Time + Cleaning Area	Lack of responsibility
34		10	Fuel	10	35	Detail	Planing	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
35		9	Fuel	9	35	Detail	Management	Yes	Don't Know	Time + Organize	Don't Know
36		13	Hydrulic	13	35	Detail	Manpower	Yes	Lack of responsibility	Time + Planing	Lack of responsibility
37		18	Hydrulic	18	35	Detail	Manpower	Yes	Regulation	Time + Organize	Regulation
38		5	Hydrulic	5	35	Detail	Parts	Yes	Lack of responsibility	Time + Cleaning Area	Lack of responsibility
39		12	Electric	12	35	Detail	Planing	Yes	Lack of communication	Time + Organize	Lack of communication
40		10	Electric	10	35	Detail	Manpower	Yes	Don't Know	Time + Cleaning Area	Don't Know
41		8	Electric	8	35	Detail	Manpower	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
42		7	Electric	7	35	Detail	Parts	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
43		9	Electric	9	35	Detail	Transportation	Yes	Lack of communication	Time + Cleaning Area	Lack of communication
44		9	Electric	9	35	Detail	Manpower	Yes	Lack of communication	Time + Organize	Lack of communication
45		10	Electric	10	35	Detail	Planing	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
46		16	Engine	16	35	Detail	Manpower	Yes	Regulation	Time + Cleaning Area	Regulation
47		18	Engine	18	35	Detail	Management	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
48		16	Engine	16	35	Detail	Manpower	Yes	Regulation	Time + Planing	Regulation
49		19	Engine	19	35	Detail	Manpower	Yes	Regulation	Time + Organize	Regulation
50		20	Engine	20	35	Detail	Planing	Yes	Lack of responsibility	Time + Planing	Lack of responsibility
51		15	Engine	15	35	Detail	Manpower	Yes	Lack of communication	Time + Organize	Lack of communication
52		21	QC	15	35	Detail	Management	Yes	Regulation	Time + Organize	Regulation
53		19	QC	10	35	Detail	Planing	Yes	Lack of responsibility	Time + Cleaning Area	Lack of responsibility
54		16	QC	9	35	Detail	Management	Yes	Lack of communication	Time + Organize	Lack of communication
55		7	QC	2	35	Detail	Parts	Yes	Don't Know	Time + Planing	Don't Know
56		9	QC	3	35	Detail	Manpower	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
57		10	ndi	10	35	Detail	Management	Yes	Regulation	Time + Planing	Regulation
58		17	ndi	17	35	Detail	Parts	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
59		11	ndi	11	35	Detail	Manpower	No	Lack of communication	Time + Organize	Lack of communication
60		12	Fabrication	12	35	Detail	Management	Yes	Lack of responsibility	Time + Organize	Lack of responsibility
61		5	Fabrication	5	35	Detail	Planing	Yes	Don't Know	Time + Organize	Don't Know
62		7	Fabrication	7	35	Detail	Manpower	Yes	Lack of responsibility	Time + Planing	Lack of responsibility
63		19	Fabrication	19	35	Detail	Manpower	No	Lack of responsibility	Time + Organize	Lack of responsibility

Appendix C. Questionnaire No. 3 (Time for completing tasks (one month))

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1						Questionnaire number 3												
2																		AVG
3	Day	Date	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12	Task 13	Task 14	Task 15	
4	Sunday	December 18, 2015	20 h	13 h	16 h	16 h	22 h	18 h	19 h	20 h								18
5	Monday	December 19, 2015	11 h	14 h	20 h	15 h	5 h	10 h	9 h	12 h	18 h	21 h	8 h					13
6	Tuesday	December 20, 2015	19 h	10 h	7 h	5 h	13 h	20 h	9 h	7 h	13 h	12 h	10 h	16 h	13 h	12 h	14 h	12
7	Wednesda	December 21, 2015	8 h	14 h	13 h	9 h	10 h	12 h	12 h	13 h	8 h	11 h						11
8	Thursday	December 22, 2015	18 h	9 h	12 h	17 h	18 h	10 h	14 h	20 h	15 h	13 h	15 h	14 h	20 h			15
9	Friday	December 23, 2015	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	N/A
10	Saturday	December 24, 2015	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	N/A
11	Sunday	December 25, 2015	15 h	12 h	9 h	16 h	18 h	16 h	14 h	12 h	15 h	13 h	14 h	12 h				14
12	Monday	December 26, 2015	20 h	17 h	18 h	15 h	18 h	17 h	12 h	15 h	15 h	17 h	14 h	19 h	14 h	13 h		16
13	Tuesday	December 27, 2015	13 h	10 h	12 h	15 h	19 h	18 h	12 h	10 h	14 h	13 h	12 h	8 h				13
14	Wednesda	December 28, 2015	20 h	15 h	19 h	18 h	19 h	18 h	20 h	24 h	19 h	18 h	17 h	22 h	19 h	20 h	17 h	19
15	Thursday	December 29, 2015	6 h	16 h	15 h	18 h	14 h	16 h	17 h	15 h	12 h	14 h	16 h	9 h				14
16	Friday	December 30, 2015	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	N/A
17	Saturday	December 31, 2015	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	N/A
18	Sunday	January 1, 2016	15 h	7 h	18 h	14 h	6 h	12 h	10 h	14 h								12
19	Monday	January 2, 2016	10 h	20 h	15 h	16 h	12 h	15 h	20 h	10 h	9 h	13 h	12 h	17 h				13
20	Tuesday	January 3, 2016	18 h	20 h	17 h	19 h	15 h	24 h	17 h	18 h	15 h	12 h	24 h	15 h	22 h	16 h		18
21	Wednesda	January 4, 2016	10 h	18 h	11 h	15 h	19 h	14 h	15 h	16 h	15 h	17 h						15
22	Thursday	January 5, 2016	5 h	7 h	8 h	12 h	18 h	15 h	13 h	15 h	9 h	8 h	11 h					11
23	Friday	January 6, 2016	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	N/A
24	Saturday	January 7, 2016	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	Weekend	N/A
25	Sunday	January 8, 2016	24 h	12 h	16 h	13 h	12 h	20 h	18 h	22 h	16 h	19 h	15 h					17
26	Monday	January 9, 2016	13 h	24 h	21 h	15 h	19 h	17 h	19 h	15 h	18 h	22 h	19 h	14 h				18
27	Tuesday	January 10, 2016	16 h	24 h	17 h	19 h	18 h	20 h	19 h	18 h	19 h	17 h	19 h	18 h	22 h	20 h		19
28	Wednesda	January 11, 2016	11 h	6 h	5 h	10 h	15 h	7 h	15 h	2 h	14 h	17 h	8 h					10
29	Thursday	January 12, 2016	16 h	18 h	17 h	19 h	14 h	15 h	7 h	12 h	17 h							15

Appendix D. Questionnaire No. 3 (Analysis Department responses)

	A	B	C	D	E
1					
2					
3					
4				Questionnaire number 3	
5				Time To change parts Depends on	Reason for Waisting Time
6			Analysis Department	Manager decision	Waiting for other shops
7			Analysis Department	Time	Waiting for parts
8			Analysis Department	Priority	Changing shifts
9			Analysis Department	Time	Transportation
10			Analysis Department	Time	Changing shifts
11			Analysis Department	Manager decision	Changing shifts
12			Analysis Department	Time	Waiting for other shops
13			Analysis Department	Priority	Changing shifts
14			Analysis Department	Time	Waiting for parts
15			Analysis Department	Time	Waiting for other shops
16			Analysis Department	Time	Changing shifts
17			Analysis Department	Manager decision	Transportation
18			Analysis Department	Time	Waiting for parts
19			Analysis Department	Time	Waiting for parts
20			Analysis Department	Priority	Waiting for other shops
21			Analysis Department	Time	Changing shifts
22			Analysis Department	Priority	Changing shifts
23			Analysis Department	Manager decision	Changing shifts
24			Analysis Department	Time	Waiting for other shops
25			Analysis Department	Time	Changing shifts
26			Analysis Department	Priority	Waiting for other shops
27			Analysis Department	Manager decision	Waiting for parts
28			Analysis Department	Manager decision	Changing shifts
29			Analysis Department	Manager decision	Changing shifts
30			Analysis Department	Priority	Waiting for parts
31			Analysis Department	Manager decision	Changing shifts
32			Analysis Department	Time	Waiting for other shops
33			Analysis Department	Priority	Transportation
34			Analysis Department	Manager decision	Changing shifts
35			Analysis Department	Time	Transportation
36			Analysis Department	Manager decision	Waiting for parts
37			Analysis Department	Priority	Waiting for other shops
38			Analysis Department	Priority	Changing shifts
39			Analysis Department	Manager decision	Changing shifts
40			Analysis Department	Time	Changing shifts
41			Analysis Department	Manager decision	Waiting for parts
42			Analysis Department	Time	Changing shifts
43			Analysis Department	Priority	Waiting for other shops
44			Analysis Department	Priority	Changing shifts
45			Analysis Department	Manager decision	Waiting for parts

Appendix E. Questionnaire No. 4 (Communication and Waiting time (3 Months data))

	A	B	C	D	E	F	G	H	I
1						Questionnaire number 4 (Communication and Waiting time (minutes)			
2									
3	Day	Date	A/C Numbe	Debrief	Aviation Ground Equipmen	First flight line	her maintenance (System ,Fabrication , Engin	Supply	Total Time
4									
5	Sunday	December 18, 2016	AC 1605	25	15	25	60	25	150
6			AC 1625	30	40	10	20	20	120
7			AC 3207	17	20	35	40	210	322
8			AC 1612	38	80	20	60	40	238
9									
10	Monday	December 19, 2015	AC 1615	50	30	40	15		135
11			AC 3201	35	35	75	40	60	245
12									
13	Tuesday	December 20, 2015	N/A						
14									
15	Wednesda	December 21, 2015	AC 1609	19	25	40	80	200	364
16			AC 1605	22	50	35	45	45	197
17			AC 3204	29	45	30	35		139
18									
19	Thursday	December 22, 2015	AC 3204	45	75	80	70	25	295
20			AC 3207	40	5	35	40	60	180
21									
22	Friday	December 23, 2015	AC 1612	25	40	55	60	30	210
23			AC 1629	35	65	15	40	80	235
24			AC 1631	15	10	45	30	20	120
25									
26	Saturday	December 24, 2015	N/A						
27									
28	Sunday	December 25, 2015	AC 1632	20	20	30	50	50	170
29			AC 3201	30	40	30	40		140
30									
31	Monday	December 26, 2015	AC 1631	25	15	30	45	25	140
32									
33	Tuesday	December 27, 2015	AC 1605	35	35	25	70	40	205
34			AC 1625	40	65	60	60	25	250
35			AC 3207	15	70	50	45	40	220
36									
37	Wednesda	December 28, 2015	AC 1629	42	50	25	75	30	222
38			AC 1631	25	50	40	35	25	175
39									
40	Thursday	December 29, 2015	AC 1609	15	10	25	40	35	125
41			AC 1605	50	35	30	25	40	180
42			AC 3204	20	20	55	80	35	210
43									
44	Friday	December 30, 2015	AC 1615	35	30	50	25		140
45			AC 3204	10	50	40			100
46									
47	Saturday	December 31, 2015	N/A						
48									
49	Sunday	January 1, 2016	N/A						
50									
51	Monday	January 2, 2016	AC 1605	45	45	30	40	20	180
52			AC 1625	15	80	35		85	215
53			AC 3207	25	20	25		30	100
54			AC 3201	20	40	80	80	40	260
55			AC 3203	30	30	45	30		135
56									
57	Tuesday	January 3, 2016	AC 1605	35	35	75	50		195
58			AC 1612	25	50	30			105
59									
60	Wednesda	January 4, 2016	AC 1605	15	35	20	20	160	250
61			AC 1612	25	60	45	50	40	220
62			AC 1631	25	30	50	60		165
63			AC 1632	15	25	55		70	165
64			AC 3201	20	15	20	75	30	160
65			AC 3204	10	5	45	35		95
66									
67	Thursday	January 5, 2016	AC 1612	10	10	40		20	80
68			AC 1631	15	30	35	70	140	290
69			AC 3204	35	40	60		40	175
70			AC 3201	20	55	70	50		195
71									
72	Friday	January 6, 2016	AC 1615	25	35	40	25	30	155
73			AC 1632	30	30	35	15	60	170
74			AC 3201	15	25	20		40	100
75			AC 3203	10	30	20	60		120
76			AC 3204	15	40	55	50		160
77			AC 3203	25	50	60	75	35	245

78									
79	Saturday	January 7, 2016	AC 1625	45	45	75		30	195
80			AC 1605	25	30	30	45	25	155
81			AC 1612	10	25	40		105	180
82			AC 3204	15	40	55	75		185
83			AC 3201	25	50	65		25	165
84									
85	Sunday	January 8, 2016	AC 1626	30	30	20	45	60	185
86			AC 1601	15	40	35	40		130
87			AC 1615	20	35	15		20	90
88			AC 3201	25	10	35	50	30	150
89			AC 3203	19	20	40	35	40	154
90									
91	Monday	January 9, 2016	AC 1631	27	50	45		50	172
92			AC 1605	25	25	80	60		190
93			AC 1601	30	30	10	45		115
94			AC 3203	45	30	50		30	155
95									
96	Tuesday	January 10, 2016	AC 1632	30	30	60	15	25	160
97			AC 1625	20	25	75	80		200
98			AC 1612	15	10	80		120	225
99			AC 3203	15	15	20	40		90
100			AC 3207	18	40	10	40		108
101									
102	Wednesda	January 11, 2016	AC 1601	40	40	55	60	35	230
103			AC 1625	25	60	25			110
104			AC 1623	15	65	10	30	30	150
105			AC 3202	25	20	40	65		150
106			AC 3207	15	35	15		190	255
107									
108	Thursday	January 12, 2016	AC 1630	30	30	60	35		155
109			AC 1625	25	10	50		50	135
110			AC 1612	15	5	40	55		115
111			AC 3202	15	15	20		90	140
112			AC 3203	15	20	60	60		155
113									
114	Friday	January 13, 2016	AC 1631	50	20	40	30	40	180
115									
116	Saturday	January 14, 2016	AC 1632	15	30	25		80	150
117			AC 3203	25	60	50	65		200
118			AC 3207	15	20	25		50	110
119									
120	Sunday	January 15, 2016	AC 1631	18	30	40	55	40	183
121			AC 1615	15	35	50	35		135
122			AC 1605	20	20	35		35	110
123			AC 3201	10	20	60	75	65	230
124									
125	Monday	January 16, 2016	AC 1601	30	30	20	15	30	125
126			AC 1615	25	55	50	35	40	205
127			AC 3203	20	10	45		25	100
128			AC 3207	20	5	10	50		85
129									
130	Tuesday	January 17, 2016	AC 1612	15	40	35	65	115	270
131			AC 1625	30	45	50		30	155
132			AC 3202	35	35	60	70		200
133			AC 3205	15	15	45		25	100
134									
135	Wednesda	January 18, 2016	AC 1605	20	35	35	45	45	180
136			AC 1630	20	55	60	80		215
137			AC 3202	15	5	55		40	115
138			AC 3207	20	20	35	50		125
139									
140	Thursday	January 19, 2016	AC 1605	27	65	50	35	75	252
141			AC 1632	30	30	20			80
142			AC 3202	45	30	25	15	50	165
143			AC 3204	35	35	40	75		185
144									
145	Thursday	January 19, 2016	AC 1601	25	15	40	45	35	160
146			AC 1612	20	35	70	65		190
147			AC 1625	15	10	50	40	30	145
148			AC 1631	25	45	35		60	165
149			AC 3202	35	35	55	30		155
150			AC 3204	30	55	40		30	155

151									
152	Friday	January 20, 2016	AC 1615	20	65	35	25	35	180
153			AC 1612	30	30	40	60	60	220
154			AC 1625	15	20	25		25	85
155			AC 3201	10	35	10	35		90
156			AC 3202	10	5	25	55	80	175
157			AC 3204	10	10	80	50		150
158									
159	Saturday	January 21, 2016	AC 1630	25	25	30	65		145
160			AC 1631	30	45	45	50	40	210
161			AC 3202	25	25	50			100
162			AC 3204	15	25	45	35	35	155
163									
164	Sunday	January 22, 2016	AC 1625	40	55	65	30		190
165			AC 1632	30	45	40		25	140
166			AC 3202	35	35	25	40		135
167			AC 3207	20	25	15	55	40	155
168									
169	Monday	January 23, 2016	AC 1615	15	40	60	45	50	210
170			AC 1632	25	25	50	35		135
171			AC 3201	30	55	65		40	190
172			AC 3203	25	15	10	45	25	120
173									
174	Tuesday	January 24, 2016	AC 1601	17	20	40	30		107
175			AC 1632	20	35	35		40	130
176			AC 3201	25	40	75	55	35	230
177			AC 3204	20	30	40	35		125
178									
179	Wednesda	January 25, 2016	AC 1605	30	45	45	60	30	210
180			AC 1625	30	65	25		25	145
181			AC 3205	40	50	35	40		165
182			AC 3207	25	25	10	50		110
183									
184	Thursday	January 26, 2016	AC 1615	20	10	45	25		100
185			AC 1632	15	35	75	20	60	205
186			AC 3204	25	25	50	40		140
187			AC 3207	30	20	55	40	40	185
188									
189	Friday	January 27, 2016	AC 1605	20	15	45	35		115
190			AC 1625	25	10	35		40	110
191			AC 3207	30	5	25	70	30	160
192			AC 1612	25	25	70	50		170
193									
194	Saturday	January 28, 2016	AC 1615	25	30	40	35		130
195			AC 3201	30	10	45	40	60	185
196									
197	Sunday	January 29, 2016	N/A						
198									
199	Monday	January 30, 2016	AC 1609	35	70	55	30		190
200			AC 1605	20	20	65		25	130
201			AC 3204	25	30	25	50		130
202								50	50
203	Tuesday	January 31, 2016	AC 3204	10	10	35	65	200	320
204			AC 3207	25	40	25			90
205									
206	Wednesda	February 1, 2016	AC 1612	35	30	40	65	60	230
207			AC 1629	25	25	55	30		135
208			AC 1631	20	75	75	40	30	240
209									
210	Thursday	February 2, 2016	N/A						
211									
212	Friday	February 3, 2016	AC 1632	35	20	80	50	40	225
213			AC 3201	30	10	45	60		145
214									
215	Saturday	February 4, 2016	AC 1631	25	30	65	40	35	195
216									
217	Sunday	February 5, 2016	AC 1605	30	25	70	35	50	210
218			AC 1625	30	10	45			85
219			AC 3207	25	5	60	60	75	225
220									
221	Monday	February 6, 2016	AC 1629	20	40	70	75	40	245
222			AC 1631	15	30	35	40		120

223									
224	Tuesday	February 7, 2016	AC 1609	40	40	50	55	50	235
225			AC 1605	25	35	60			120
226			AC 3204	20	40	75	80	90	305
227									
228	Wednesd	February 8, 2016	AC 1615	15	20	25	50	60	170
229			AC 3204	20	45	40	75		180
230									
231	Thursday	February 9, 2016	N/A						
232									
233	Friday	February 10, 2016	AC 1630	25	55	35	45	240	400
234			AC 3207	15	20	55		130	220
235									
236	Saturday	February 11, 2016	AC 1605	25	45	25	50		145
237			AC 1625	20	20	60	25	60	185
238			AC 3207	30	30	45	55		160
239			AC 3201	40	10	60	15	125	250
240			AC 3203	10	20	75			105
241									
242	Sunday	February 12, 2016	AC 1605	50	50	10	45	45	200
243			AC 1612	15	30	55	60		160
244									
245	Monday	February 13, 2016	AC 1605	30	45	75	60	35	245
246			AC 1612	25	25	45	35		130
247			AC 1631	15	10	30	65	55	175
248			AC 1632	30	25	75	80		210
249			AC 3201	15	5	40	35	20	115
250			AC 3204	10	60	45	40		155
251									
252	Tuesday	February 14, 2016	AC 1612	25	45	50	35	125	280
253			AC 1631	30	25	65	50		170
254			AC 3204	25	30	30	35	100	220
255			AC 3201	30	15	45			90
256									
257	Wednesd	February 15, 2016	AC 1615	30	10	70	45		155
258			AC 1632	35	40	50		40	165
259			AC 3201	25	30	45	35	90	225
260			AC 3203	25	5	30	70		130
261			AC 3204	10	35	25	40	25	135
262			AC 3203	30	15	60	55	45	205
263									
264	Thursday	February 16, 2016	AC 1625	20	25	65	40		150
265			AC 1605	35	35	70	35	70	245
266			AC 1612	10	45	35	30		120
267			AC 3204	45	50	25	25	45	190
268			AC 3201	20	75	45	20	35	195
269									
270	Friday	February 17, 2016	AC 1626	20	35	70	50	60	235
271			AC 1601	25	25	35	35		120
272			AC 1615	30	10	45	60	40	185
273			AC 3201	30	30	80	40		180
274			AC 3203	35	50	75	50	65	275
275									
276	Saturday	February 18, 2016	AC 1631	15	45	50	40	25	175
277			AC 1605	20	20	60	30	130	260
278			AC 1601	25	15	30	40		110
279			AC 3203	25	25	50	60	65	225
280									
281	Sunday	February 19, 2016	AC 1632	35	40	35	45	55	210
282			AC 1625	35	25	40	80		180
283			AC 1612	20	15	55		230	320
284			AC 3203	20	20	10	40		90
285			AC 3207	25	10	35	55	40	165
286									
287	Monday	February 20, 2016	AC 1601	15	15	50	60	45	185
288			AC 1625	40	30	40	45		155
289			AC 1623	30	25	60		35	150
290			AC 3202	35	25	55	60		175
291			AC 3207	20	10	20	15	60	125

292									
293	Tuesday	February 21, 2016	AC 1630	25	40	45	35	30	175
294			AC 1625	30	25	65	50		170
295			AC 1612	25	10	60	15	125	235
296			AC 3202	20	5	50	30		105
297			AC 3203	15	15	35	40	115	220
298									
299	Wednesda	February 22, 2016	AC 1631	30	55	45		65	195
300									
301	Thursday	February 23, 2016	AC 1632	40	25	65	35	30	195
302			AC 3203	25	40	25	45		135
303			AC 3207	30	35	45	65	35	210
304									
305	Friday	February 24, 2016	AC 1631	20	45	60	75	220	420
306			AC 1615	30	60	45	30	40	205
307			AC 1605	40	20	40		50	150
308			AC 3201	20	30	55	40		145
309									
310	Saturday	February 25, 2016	AC 1601	20	35	15	35	65	170
311			AC 1615	25	25	55	45		150
312			AC 3203	30	10	45	30	130	245
313			AC 3207	35	20	70	50	50	225
314									
315	Sunday	February 26, 2016	AC 1612	25	25	30	75	160	315
316			AC 1625	30	15	45	30		120
317			AC 3202	25	25	30	25	60	165
318			AC 3205	25	20	45	30	100	220
319									
320	Monday	February 27, 2016	AC 1605	30	5	60	40	105	240
321			AC 1630	25	25	70	25		145
322			AC 3202	15	40	45	60	95	255
323			AC 3207	50	50	50	55	75	280
324									
325	Tuesday	February 28, 2016	AC 1605	25	25	45	35		130
326			AC 1632	30	15	60	75	50	230
327			AC 3202	15	15	25	35		90
328			AC 3204	20	50	20	45	45	180
329									
330	Wednesda	February 29, 2016	AC 1601	20	30	50		40	140
331			AC 1612	30	25	55	75		185
332			AC 1625	30	45	40	55	120	290
333			AC 1631	15	55	30	65	70	235
334			AC 3202	10	15	55	45	90	215
335			AC 3204	25	30	35			90
336									
337	Thursday	March 1, 2016	AC 1615	20	30	50	45	20	165
338			AC 1612	30	30	40		40	140
339			AC 1625	25	15	45	35	65	185
340			AC 3201	40	35	65	40		180
341			AC 3202	25	10	70	80	45	230
342			AC 3204	10	25	40		75	150
343									
344	Friday	March 2, 2016	AC 1630	25	30	35	25	80	195
345			AC 1631	20	25	40	35	45	165
346			AC 3202	50	10	65			125
347			AC 3204	10	25	40	55	160	290
348									
349	Saturday	March 3, 2016	AC 1625	15	35	50	65	30	195
350			AC 1632	28	20	40			88
351			AC 3202	34	10	55	80	40	219
352			AC 3207	29	45	50	45		169
353									
354	Sunday	March 4, 2016	AC 1615	18	20	45		30	113
355			AC 1632	29	35	60	30	40	194
356			AC 3201	30	25	40	55		150
357			AC 3203	43	25	30	35	90	223
358									
359	Monday	March 5, 2016	AC 1601	20	40	55	45	100	260
360			AC 1632	30	25	35	65		155
361			AC 3201	10	15	70	80	110	285
362			AC 3204	15	30	60	60		165

363									
364	Tuesday	March 6, 2016	AC 1605	45	25	30	15	180	295
365			AC 1625	30	10	45	45		130
366			AC 3205	15	15	60	40	35	165
367			AC 3207	20	5	55			80
368									
369	Wednesda	March 7, 2016	AC 1615	20	20	45	60	220	365
370			AC 1632	14	30	30	55		129
371			AC 3204	40	45	45	70	40	240
372			AC 3207	25	10	80	35		150
373									
374	Thursday	March 8, 2016	AC 1631	25	35	30	35	20	145
375									
376	Friday	March 9, 2016	AC 1605	30	40	45	50	50	215
377			AC 1625	35	35	60	55		185
378			AC 3207	20	10	65	25	130	250
379									
380	Saturday	March 10, 2016	AC 1629	15	40	45	15	70	185
381			AC 1631	30	25	75	30	60	220
382									
383	Sunday	March 11, 2016	AC 1609	20	35	30	25	120	230
384			AC 1605	25	55	60	45		185
385			AC 3204	30	25	70	50	210	385
386									
387	Monday	March 12, 2016	AC 1615	25	25	40	40	60	190
388			AC 3204	15	40	35			90
389									
390	Tuesday	March 13, 2016	N/A						
391									
392	Wednesda	March 14, 2016	AC 1615	40	40	10	45	40	175
393			AC 3204	25	30	60		50	165
394									
395	Thursday	March 15, 2016	AC 1605	30	25	55	50	90	250
396			AC 1625	25	10	60	70	50	215
397			AC 3207	30	30	25	30		115
398			AC 3201	15	25	60	15	50	165
399			AC 3203	40	55	70	20		185
400									
401	Friday	March 16, 2016	AC 1605	15	25	65	50	240	395
402			AC 1612	20	20	40	30		110
403									
404	Saturday	March 17, 2016	AC 1605	20	70	50	40	200	380
405			AC 1612	30	55	60	60		205
406			AC 1631	25	25	70	30	150	300
407			AC 1632	30	10	40	35		115
408			AC 3201	10	55	25	60	20	170
409			AC 3204	25	35	25			85
410									
411	Sunday	March 18, 2016	AC 1612	30	45	50	40	30	195
412			AC 1631	25	60	60	30	40	215
413			AC 3204	30	15	75	45	130	295
414			AC 3201	20	20	30	35		105

Appendix F. Questionnaire No. 5 Responses

	A	B
1	Questionnaire number 5	
2		
3	Pilot Rank	What could improve the process
4	COL	Reduce waiting time
5	COL	Raise morale
6	COL	Raise morale
7	Lt COL	Team work
8	Lt COL	Team work
9	Lt COL	Reduce waiting time
10	Major	Raise morale
11	Major	Team work
12	Major	Reduce waiting time
13	Major	Planning
14	Captain	Planning
15	Captain	Reduce waiting time
16	Captain	Planning
17	Captain	Reduce waiting time
18	Lt	Raise morale
19	Lt	Raise morale
20	Lt	Team work

APPLYING LEAN TO THE AC-130 MAINTENANCE PROCESS FOR THE ROYAL SAUDI AIR FORCE

Capt. Fisal Ali Alzahrani, RSAF
Advisor: Capt. Michael P. Kretser, PhD, USAF
Department of Operational Sciences (ENS)
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Introduction

The AC-130 maintenance process needs to improve cycle time and reliability, improve safety, and improve availability of aircraft. This can be done by improving communication, reducing distances needed to move or transport equipment during the maintenance process and by efficient use of the available qualified workforces, tools, and equipment.

Consideration is given to applying existing management techniques to the Royal Saudi Air Force's AC-130 Maintenance Squadrons. Once reviewed, the selected technique was the "Lean" management approach. The purpose of Lean is to reduce costs, eliminate waste, increase efficiency, improve product quality, maximize value to the customer and provide greater availability and quicker maintenance turnaround of C-130s.

Research Questions

1. What impact does Lean Processes have on the RSAF AC-130 maintenance processes?
2. By applying Lean plans, what will be the reduction for the cycle time?
3. What are the challenges of applying Lean?

Lean Principles

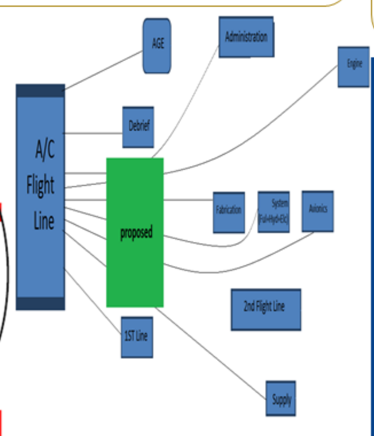
Methodology

Map the current process
- Identify the wastes.
- Eliminate the wastes.

Questinnaries
- Determine how lean could help improve the process

Reviewed the entire processes
- Determine the number of "steps".
- Look for challenges.
- Recommend actions.

The Current Processes



Recommended Location

Reduction when Lean is implemented

Department	Communication and waiting time (minutes)		Proposed	Reduction	
	Standard	Worst		Standard	Worst
Debrief	10	50	5	50%	90%
Aviation Ground Equipment	5	80	2	60%	97%
First flight line	10	80	2	25%	97%
Other maintenance	15	80	2	15%	97%
Supply	20	240	10	50%	96%
Total Cycle Time	60	530	21	65%	96%

Department	Distance (m)	Proposed (m)	Reduction
Debrief	400 m	200 m	50%
Aviation Ground Equipment	300 m	200 m	33%
First flight line	200 m	200 m	0%
Fabrication	1200 m	200 m	83%
System (fuel +hydrulic+electric)	1500 m	200 m	86%
Avionics	1800 m	200 m	89%
Engine	2500 m	200 m	92%
Supply	3000 m	200 m	93%

Results and Conclusions

The goal was to use the Lean tool that, if effective, would greatly help managers to make decisions over the maintenance process to improve the efficiency.

To improve the process and make the reduction in C-130 maintenance process we recommend the Royal Saudi Air Force to eliminate time that been wasted in waiting and unnecessary communication. Another major thing Royal Saudi Air Force should consider is to shorten the distance between maintenance shops, supply and Aviation Ground Equipment.

The research recommend to take at least the next implementation actions:

1. Improve the process by eliminating time that is been wasted in waiting and extra communication.
2. Shorten the distance between maintenance shops, supply and Aviation Ground Equipment (by utilizing the buildings by the flight line).
3. Manage tool access to ensure that there is no wasted time spent either locating a missing tool or retrieving a tool.
4. Use a computer system.

DEPARTMENT OF OPERATIONAL SCIENCES

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Vita

Captain Fisal Alzahrani from Royal Saudi Air Force. Studied and graduated from Alabna schools in Riyadh the capital of Saudi Arabia. He entered undergraduate studies at the National University of since and Technology at Pakistan, where he graduated with a Bachelor degree in Avionics Engineering in December 2009.

His first assignment for Captain Alzahrani was at Prince Sultan Air Base at AlKharj as a C-130 maintenance officer. He has been stationed in many other places around Saudi Arabia for TDY and job courses. In September 2014 he entered the Graduate School of Engineering and Management, Air Force Institute of Technology.

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14. ABSTRACT The ideas expressed in this research come from the researcher's experiences working in the AC-130 maintenance squadron in the Royal Saudi Air Force. The AC-130 maintenance process is not currently being used as effectively as it could be to make AC-130 fully mission capable. That can be done by improving communication, reducing distances needed to move or transport anything during the maintenance process and by efficient use of the available qualified workforces, tools and equipment. Consideration is given to applying an existing management technique to the Royal Saudi Air Force's AC-130 Maintenance Squadrons. The selected technique is the "Lean" management approach. The research suggests that Lean can help and improve AC-130 maintenance process in the Royal Saudi Air Force for several reasons. One of the most important reasons of using Lean is that it will get rid of waste and measure the process improvement of C-130s. If Lean is implemented, there will be reduction of (65%-96%) on the cycle time. The bottom line benefit that the research suggests is to minimize the time required to maintain the aircraft C-130 and improve the availability rate.					
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