



**Evaluating Opportunities for Improved Processes and Flow Rates in the
Royal Saudi Air Force F-15 Reparable Items Supply Chain**

THESIS

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Captain, RSAF

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Abstract

This research focuses on improving the F-15 reparable parts supply chain process, in the Royal Saudi Air Force. The F-15 reparable parts supply chain process currently requires too much time to repair and return parts, which affects the capability of aircraft operational missions. Because the F-15 is the first line of Saudi Arabia's defense, it is essential that they be fully-capable of missions in the shortest time possible. This can be done by improving relationships, communication, reducing batching before shipments, 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 F-15 supply chain. The selected techniques are supply chain mapping, the lean management approach, and gap analysis. The research suggests that these techniques can improve F-15 supply chain processes in the Royal Saudi Air Force.

To my parents

To my wife

To my little princess

To my country

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Ali A. Alshehri

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Evaluating Opportunities for Improved Processes and Flow Rates in the Royal Saudi Air Force F-15 Reparable Items Supply Chain

I. Introduction

Overview

The readiness of the Royal Saudi Air Force (RSAF) F-15 fleet is of vital importance to the security of the Kingdom of Saudi Arabia - one of the most important countries in the world, and a key player in the maintenance of regional stability. The RSAF must maintain capability to fulfill its security obligations, both at home and in the region. Other members of the Islamic world also depend upon Saudi Arabia as the land of the prophet Muhammad (peace be upon him), and the protector of the Islamic sanctities. Therefore, Saudi Arabia must be able to meet security challenges and respond to issues that concern not only its own community, but other Muslim communities around the world. Commercially, Saudi Arabia is one of the top oil producers in the world, which currently plays a major role in the world economy. This, plus the obligation of protection, provides the reason why Saudi Arabia built its defense systems. The centerpiece of the defense system is the airpower of the Royal Saudi Air Force, which is one of the branches of the Ministry of Defense (MOD), the cornerstone of capability being the fleet of F- 15C/D/S, and the new Saudi Advanced (SA) F-15 aircrafts. The RSAF maintains and operates a large fleet of F-15 fighter aircrafts: currently ~150 aircrafts, which is expected to grow to over 225 by 2021 (AFLCMC/WWQI 2015). These, along with other fleets of modern fighter jets, are utilized by the RSAF to defend their interests with constant vigilance.

To support long term defense, the RSAF developed a requirement for a Fleet Modernization Program (FMP), which was formalized as a Foreign Military Sales (FMS)

program through a Letter of Agreement (LOA) from Saudi Arabia to the United States Department of State (AFLCMC/WWQI 2015). The United States Air Force is the implementing agency for the LOA, which is managed by the Security Assistance Program Manager (SAPM), whom directs the office that executes the program. Recently, the SAPM signed contracts on behalf of the RSAF with Boeing, to modernize 70 existing F-15S fighters and produce 84 new SA fighters, in one of the biggest military FMS contracts in history. This historic contract demonstrates the RSAF's importance as an ally of the United States Air Force, and the emergence of Saudi Arabia as one of the biggest customers of the Boeing Company.

With a larger fleet of F-15 fighters comes the necessity for larger and better supply chains; increasing the efficiency of the management of these chains, as well as the growing operational requirements of the RSAF, is the purpose of this discussion and analysis.

The current material management system is not up to the expectations of RSAF supply managers or operational commanders (Royal Saudi Air Force Interviews 2015). The ability of the RSAF to maintain its mission readiness has been negatively impacted by the current supply chain end-to-end times, with gaps in inventory management. Therefore, the end-to-end supply chain process has been mapped and analyzed to identify what parts of the supply chain can be improved, in order optimize performance.

Based on ongoing analysis by the RSAF and the United States Air Force (AFLCMC/WWQI), it has become apparent that the study of the enterprise level of the Royal Saudi Air Force F-15 supply chain represents the key to evaluating and identifying the bottlenecks and gaps, which limit and constrain the supply chain performance in delivering

repaired parts in shortest possible time. To date, supply chain improvement initiatives by the RSAF supply managers have been undertaken to eliminate any waste within the supply chain internal processes, but these initiatives have not yet studied the problem at the enterprise level. As a result of initiatives begun by the RSAF Director of Supply (DOS), supply managers, and senior leaders in the Sustainment Branch of F-15, as well as the Saudi Arabia Country Manager in the FMS Technical Coordination Program at Robins AFB, a Continuous Process Improvement (CPI) program has begun. This CPI program is aimed at improving the communication process between the bases and depot supply, and the sources of repair (SOR). Using studies and analyses that date from 2009, as well as fresh Value Stream Mapping (VSM), the improvements are moving in a positive direction. This research examines those studies and findings, as well as results from focused interviews, to identify gaps and potential root causes. This research will also recommend what management actions could be taken to improve the overall supply chain performance, in order to meet operational requirements.

How Does The System Work?

When a part breaks on an aircraft, it is the responsibility of the maintenance technicians to remove the part from the aircraft, and to open a work order in GOLDesp (the software used to help in logistics management). The part then begins a long trip through a series of processes within the maintenance squadron. Then, the part is submitted to base supply and prepared to be shipped to the depot supply in Daharn (an eastern region of Saudi Arabia). In the depot supply, the part also passes through a series of inspections and documentation requirements. The operators in the depot identify the SOR for each part, and submit it to the contracted freight forwarder (FF), who ships each part to the identified SOR. Each SOR schedules parts repair, and

after repairing, the old part is submitted back to the FF, who returns it the depot supply. The depot supply then distributes the part to one of the four bases, according to the shipping requirements.

The F-15 program office at Robins AFB performed a detailed VSM of base and depot supply processes. These results may be beneficial for this study, to analyze bases and depot supply, in case the study recommends a deeper analysis for them. Generally speaking, this study takes an aerial view at the enterprise level of the supply chain system, to identify the bigger gaps which may limit the system's ability to return any given repaired part in a shorter period of time. The supply chain managers in the RSAF headquarters postulate that the SOR takes extensive time in repairing parts. This longer-than-anticipated "turnaround time" lead to the initialization of the Lean method. This study will analyze the system as a whole, seeking and identifying limitations in the supply chain.

Supply Chain Mapping

The nature of any firm is that it exists in a chain of suppliers and customers. It is the responsibility of managers to oversee the relationships of their firm with other firms that exist in the same supply chain. "Mapping of the supply chain is the first step to solve any problem and improve the environment of the supply chain" (Lambert, 2014).

Lean

Lean is a management method that was developed to improve the productivity of the processing and quality of products. Toyota was the innovator of this technique, using it to compete against other automotive companies for a long time. Many commercial companies and

government organizations eventually adopted the Lean method to successfully improve their processes (Womack J. P., 2007). Lean is mainly about eliminating any waste in the supply process, making continuous improvements along the way. In the RSAF supply system, the waste can be defined the unreasonably length of time when parts sit idle. This research proposes to apply the Lean concepts to the overall system, to identify where the waste accrues. By applying this method of management thinking, the waste time can be accurately identified, which increases efficiency (and therefor speed). This will result in higher aircraft availability, which allows the RSAF to meet its operational requirements.

Problem Statement

The time of the F-15 parts repair and return is unreasonably long, and undefined, under the current material management system. This lengthened time of reparable part supply affects the ability of the F-15 maintenance squadrons to meet the operational requirements of the RSAF.

Research Objectives/Question

Research Objective:

This research seeks to achieve many objectives; the most important being identification of gaps at the enterprise level of the supply chain that constrain and limit the chain from supplying reparable parts in a shorter and more-defined time frame. By making these identifications, the RSAF will be able to increase the mission capabilities of its aircrafts.

Research Questions

Q1: What processes does the end-to-end map of the SCM value chain currently encompass?

Q2: When do the steps defined in the SCM start and stop?

Q3: Who are the process owners for applicable regulations, policies, and procedures?

Q4: What factors govern the current output of the system?

Research Focus

This research focuses on the repair and return of F-15 reparable parts at the enterprise level of the supply chain, to capture the big picture of the process, and allow researchers to identify major gaps in the process, which will lead to suggestions for deeper analysis to evaluate the causes of delay within each station of the process. Supply chain mapping and Lean techniques will be used to identify time waste and suggest further solutions.

Methodology

The researcher will use supply chain mapping and Lean techniques to analyze processes and flow times of the enterprise supply chain, compare them with best/expected flow times, and identify gaps and bottlenecks in the process. The data needed is available and provided by the RSAF supply directorate, and the program office. This research deals with available resources, and will not attempt to go deeply into any financial matter or administration process. It will focus primarily on the enterprise level of the reparable parts supply chain.

Implications

The outcome of this research may directly contribute to current RSAF Lean initiatives,

and is expected to contribute to the development of FMS sustainment contracts resulting from current Saudi Arabian F-15 FMP LOA guidance.

Preview

The objective of this analysis is to define the enterprise level process, and the service time at each supply chain station, and compare those results to a defined estimated delivery time of repaired parts, leading to the elimination of any steps that create waste in the process. This will enhance the supply chain time, and increase the visibility of materials during the trip to and from repair sources. By achieving this, the capability of the F-15 fleet will be able to meet the RSAF's operational requirements.

II. Literature Review

Chapter Overview

This chapter presents an overview of the salient material investigated while researching the problem statement of this thesis. Only the literature considered helpful in analyzing this problem is mentioned here.

What is Supply Chain Management?

The definition of supply chain management is a key starting point in the analysis of any supply chain. But before defining supply chain management, it is important to understand what a supply chain is. Lambert (2014) defined supply chains as: “A chain of firms or organizations work with each other as suppliers and customer for each other to deliver products or services for the end consumers”. It is important to acknowledge that managing a supply chain requires a variety of business functions with any firm or organization associated with said chain.

Relationships in the Supply Chain

To create a strong supply chain, relationships between the supply chain members must be strongly developed and maintained. To build a high-performance relationship, the firm’s managers need to develop strategies that determine what goals they need to achieve with such a relationship, and then form a cross-function team from every organization within the supply chain.

This cross-functional team can then develop operational plans to implement the goals of the supply chain (Lambert, 2014).

Supply Chain Mapping

The nature of any firm is that it exists in a chain of suppliers and customers, and it is the responsibility of managers to oversee the relationships of their firm with other firms that exist in the same supply chain. Managers of these relationships report on each step in the chain, starting with the source of the raw materials and ending with the consumer of the final product or service, to create a better visibility of any activity that occurs within that chain. It is difficult to create such visibility in a complex network of relationships, but utilization of supply chain mapping to encompass all the organizations that exist within the supply chain allows for successful management of those relationships.

Supply chain mapping requires immense effort and data from each organization in the supply chain, to help understand the nature of the relationships that need to be established with each firm. Mapping of the supply chain provides managers with a complete view over the enterprise level of activities, and identify any limitations or areas of waste in the supply chain. Mapping involves not only gathering data about suppliers or customers, but also analysis to create a stronger, more complete, mapping of the supply chain.

Mapping the supply chain is an important first step in managing relationships within the chain. It helps in classifying customers and assists in serving them accordingly, creating a competitive environment for the firms. This improves both the supplier's performance, and the customer's ability to manage their inventory, which makes decisions about outsourcing for potential suppliers possible.

Relationship-based Map

The use of relationship-based maps is very helpful in allocating resources, as well as managing relationships, between the focal company and other firms in the supply chain. Supply chain mapping is the first step towards promoting a clear understanding about the business processes of any firm's supply chain, which in turn helps managers to see potential improvements or risks, which can be difficult to identify without mapping.

It is the responsibility of managers to create better relationships with suppliers or customers beyond direct sales. Mapping the supply chain based on relationships will help in identifying the opportunities of outsourcing, and will assist in better marketing decisions as well. The primary advantage of relationship-based mapping is its ability to reduce the complexity of the supply chain network, making it more manageable.

It is necessary to use mapping in identifying the nature of the members in the supply chain, whether they are primary or supporting members. Primary members are the firms who add value to the real process of the supply chain, and the supporting members are those who support the process by providing training, resources, and facilities to the primary members of the supply chain. Some companies can be both primary and supporting members at the same time. Identifying who is primary and who is supporting is not always an easy job to do, and supply chain mapping helps managers to make that distinction between firms. This identification provides the guidelines for managers to manage the relationships within their chain.

It is vital to represent the strength of relationships in the maps, to help managers monitor important relationships closely; based on case-by-case needs, some relationships are more critical for the organization to manage than others. For that, there are different types of business

process links that can be used to represent the strength of relationships in the supply chain mapping (Lambert, 2014).

Lambert (2014, pp. 210-213) indicates that: “Four fundamentally different types of business process links can be identified between members of a supply chain: managed process links, monitored process links, not-managed process links and non-member process links.

Managed Process Links: Managed process links are those that management of the focal company finds important to integrate and manage. In the supply chain shown in Figure 1, the managed process links are indicated by the thickest solid lines. The focal company will integrate and manage process links with Tier 1 customers and suppliers as well as with key firms beyond Tier 1.

Monitored Process Links: Monitored process links are not as critical to the focal company; however it is important to the focal company that these process links are integrated and managed appropriately between the other member companies. Thus, the focal company, as frequently as necessary, simply monitors or audits how the process link is integrated and managed. The thick dashed lines in Figure 1 indicate the monitored process links.

Not-managed Process Links: Not-managed process links are links that the focal company is not actively managing, nor are they critical enough to use resources for monitoring. In other words, the focal company fully trusts the other members to manage the process links appropriately, or because of limited resources leaves it up to them. The thin solid lines in Figure 1 indicate the not-managed process links.

Non-member Process Links: Managers should be aware that their supply chains are influenced by decisions made in other connected supply chains. For example, a supplier to the focal company is a supplier to the chief competitor which may have implications for the supplier's allocation of manpower to the focal company's development and product commercialization process, availability of products in times of shortage, and/or protection of confidentiality of information. Non-member process links are links between members of the focal company's supply chain and non-members of the supply chain. Non-member links are not considered as links supply chain structure, but they often affect the of the focal company's performance of the focal company and its supply chain. The thin dashed lines in figure 1 illustrate examples of non-member process links.”

The supply chain mapping must be easy to build, and should provide better visibility of the network of the firms in the supply chain. Additionally, it must have complete details about the business process supported with accurate data. Supply chain maps must be current to enable managers to make better decisions to avoid risks and exploit opportunities. Managers must be aware of mapping risks which can negatively impact the organization's position (such as exposing confidential information). Like any project, supply chain maps must be validated by the process owners to be more applicable and represent the reality of the supply chain (Gardner & Cooper, 2003).

Value Stream Mapping Tools

Value stream maps are usually used to identify gaps and waste in the value stream, to help in improving the flow of any process, by eliminating those wastes or at least reducing them and their effect on the value stream. There are three different types of processes, which are based on their value added to the final output. The first is complete waste, which adds no value; these kinds of processes must be eliminated.

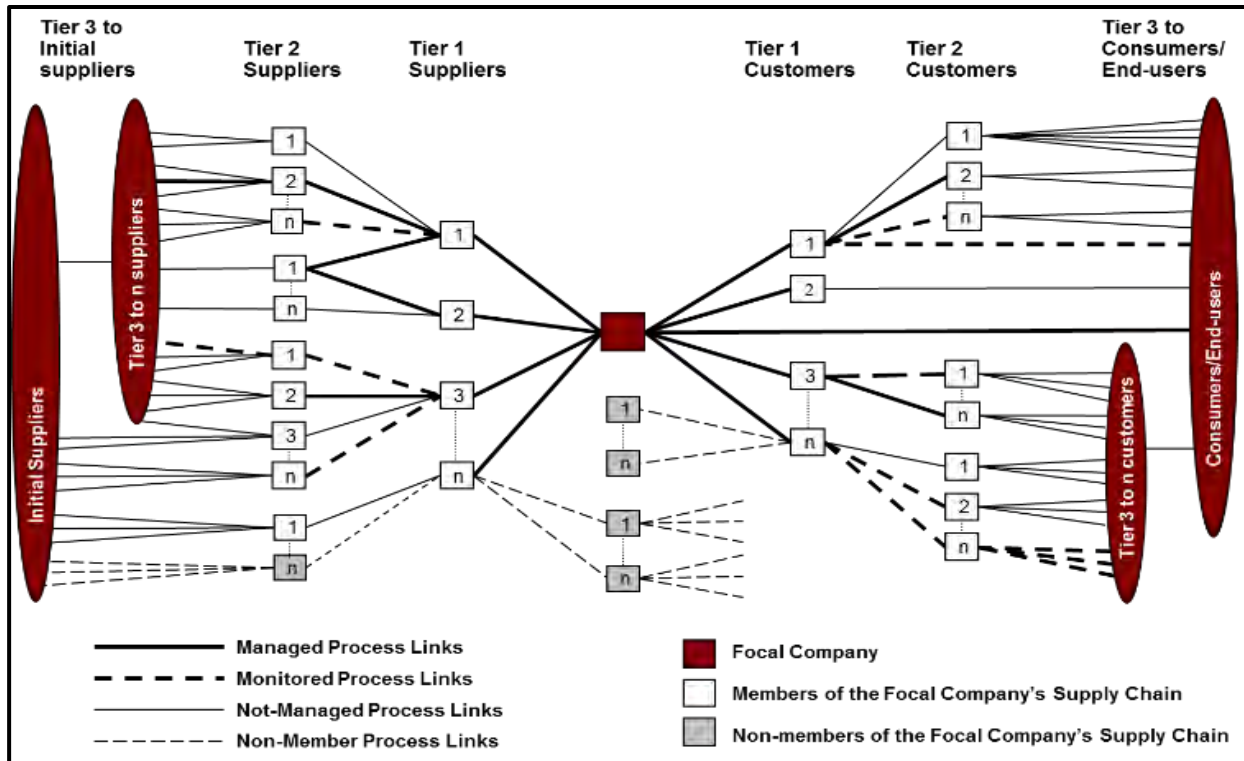


Figure 1 Types of inter-company business process links Lambert (2014,pp.211)

Business Process Improvement

For any business, the final output needs to go through many processes, starting at the originator and ending at the finished product or service. These processes must be healthy enough to face any changes and challenges that could limit the abilities of the business process to meet the targeted expectations. When the process fails to meet expectations, some managers think it is the employees' fault; often, however, it is not. It fails because the process is not able to cope and adapt with changes and complexities over time. Managers must encourage their employees to help improvements teams, by notifying them about any shortage or problems in the process, rather than blaming employees for processing failures (Abudi, 2010).

Improvement of any business process is a continuous effort to ensure that the business process is healthy and able to create the best value. Business process improvement is a cyclic process, initiated by defining the goals and targeted results then collecting data and measuring the performance of the system for analysis and comparison to identify the gaps in the process between real performance and targeted expectations. After identification of the gaps in the process, one can improve the process by closing those gaps, returning afterwards to set further goals, maintain performance, and continuously measure performance to remove failures, which could result as requirements and goals change (Keller, 2011).

Business process improvements can be done by statistical methods or by theoretical methods; all are aimed toward helping process managers utilize higher percentages of their process efficiency. Two of the most famous methods of utilizing and improving process performance are Lean-six sigma and process mapping. Those methods have proved their ability to improve the business process in many organizations, both government and private (Siha & Saad, 2008).

Lean History

Whenever Lean is mentioned, the name of Toyota production executive Taiichi Ohno is surely followed, as he was the first person to use the principles of Lean management in the early 1960's. He was the enemy of any kind of “muda”, or waste, in the production process, and made Toyota a leader in the automotive market in terms of production numbers. Using Ohno's way of thinking, Toyota shortened the time it took to change dies from a day to three minutes. His thinking was basically eliminating any activity that added no value to the final products (Womack, 2007).

The ideal result in any process is to achieve the highest quality possible, with no waste, and a satisfied customer. It is important for the process managers to understand what exactly needs to be produced, when, where, how much it will cost, and the required quality. Understanding customers' needs and the ability of how the process can meet those needs, is central to achieve the highest satisfaction.

The three M's in Ohno's methodology are: "Muda, Muri and Mura" - waste, unevenness, and overburden. If, in any production, there is "Muri" or "Mura", that means there is waste. It could be waste of time, materials, etc... Ohno has identified seven types of waste in the Toyota production process, which could be applicable in any other process, as there are many forms of waste which can exist in any process. Those seven types of waste are:

1. Mistakes.
2. Producing items no one needs.
3. Any non-adding value processing steps.
4. Employee's movement without purpose.
5. Transportation of goods from location to another without purpose.
6. Workers downstream waiting for upstream activity to end.
7. Products don't meet the customer satisfaction (Womack & Jones, 2003).

Lean Principles

Lean Thinking is a management technique aimed to produce the best value with minimal waste. Satisfaction of all the members of a supply chain is the objective of Lean thinking management. This satisfaction can be achieved by knowing the five key points of Lean:

1. Setting the value the customer expects in terms of quality and cost and focusing all activities in the organization toward achieving that value.
2. Set every step in the process to achieve that value by creating a value stream from the raw material to final goods. It is important to know that the process is as good as the weakest step in the process.
3. Keep the products moving in smooth flow avoiding any batching or queuing in the process which can disturb the flow. This can be accomplished after eliminating any waste in the process and then creating better output of the weakest link or what is called “bottleneck”.
4. Make customers pull products and operate the system as needed in a quick response to customer demand thus avoiding overproduction.
5. Implementing the previous points on a process makes perfection more achievable. Perfection means the process can be successful in delivering the right quality with perfect value to the customer at the right time with zero waste in time or materials at the right cost (Womack & Jones, 2003).

Six Sigma

Motorola invented the six sigma method to manage their production process. The Six sigma method not only improved the production process, but also improved the employees' performance, and the way managers are involved in the process. The six sigma method is about controlling fluctuation in the process (Siha & Saad, 2008). Six sigma is most readily used when variability is a big concern in the process (Anupindi et al, 2011).

How Does Lean Relate to Government?

Lean started in the manufacturing sector to improve productivity, but after demonstrating its success, it has become widely adopted in the service sector to help with many managerial issues. Many United States government agencies initiated Lean events in the past decade, to help managers make better decisions in order to improve customer service, financial issues, and demand management. Also, military branches recognized the effectiveness of Lean techniques, and initiated many events to improve the processes and eliminate possible waste in many systems.

Cause-and-Effect Diagram

This tool is used to find roots that cause any issue in processes by asking: “what causes that issue, and why does it happen?” The answer to these questions will lead to other questions until the main reason, the root of the problem, is identified. This process is known as the “five whys” method, and is useful for identifying the root of any issue. It is essential to reach to the root of any problem in order to solve the problem permanently.

Evaluate Performance

Like any other system, managers need to evaluate and analyze the results of Lean when they decide to implement it in their organization. Any efforts of improvement must be continuously monitored by leaders and managers, and it is also important to get feedback from subordinate employees. The metrics of performance evaluation must be identified during meetings before starting any Lean study. Managers must keep a close eye on the system to be sure to meet the objectives of any Lean event initiated in their organization (states, 2011).

The ABC Analysis

In inventory management, the ABC analysis is a categorization of inventory based upon dollar value. The A category is the small percentage of the inventory which makes the highest dollar value. And the C category is wider percentage of the category but makes the least percentage of the dollar value. Category A will need close management and better relationship with suppliers, as it makes the highest share of the revenue, whereas Category C is the least dollar value, so it needs less management and attention. This analysis will help managers of the inventory to manage their inventory category by category, instead of meticulously individualizing items. Managers can also classify their suppliers and customers based on value in the same regards which can reinforce strong supply chain management (Flores & Whybark, 1986).

Gap Analysis

When business managers implement and maintain improvements, gap analysis is used to examine and evaluate the improvement's effectiveness. The method of conducting gap analysis is, to determine which supply chain components must be improved, and set goals or expectations for those improvements. After implementing the improvements on the process, the results of the improvements should be compared with the expected goals, and if the difference between the goals and actual score is high, that indicates that managers need to close the gap.

Managing gaps in the process may need re-allocation of resources to improve the scores of process performances. First, list all of the gaps, and identify how each gap is critical to the whole process and its degree of variation from the expected goal. Then establish an action plan to implement the changes over time, under a cross-functional team, to insure

perfect implementation and resolve the gaps in the process (Lambert, 2014).

Past Lean Events Done on RSAF F-15 Supply Chain

The RSAF initiated a Lean event on F-15 parts repair and return supply chain in 2009, in cooperation with the F-15 program office in Robins AFB, to improve the efficiency and readiness of the F-15 air fighter fleet. The aim of the Lean event was to accomplish continuous process improvement. Many results and changes have taken place in past years, and some improvements have been achieved in the supply chain, but the full expectations for improved supply chain performance have not yet been achieved.

For that reason, the RSAF and United States Air Force managers of the F-15 parts supply chain need to further study the entire supply chain, and focus on what can be done to link all processes needed, to improve performance. Past studies mapped the process of the supply chain, from depot supply to source of repair and back, but did not include the bases in the analysis. The end to end process map done in the past Lean event is shown in Figure 2. The study ended with recommendations to continuously improve and execute the value stream maps done during the Lean event. Subsequently, the RSAF and United States Air Force supply chain managers teamed up to continue addressing the many issues in the supply chain, as part of ongoing efforts for continuous process improvement.

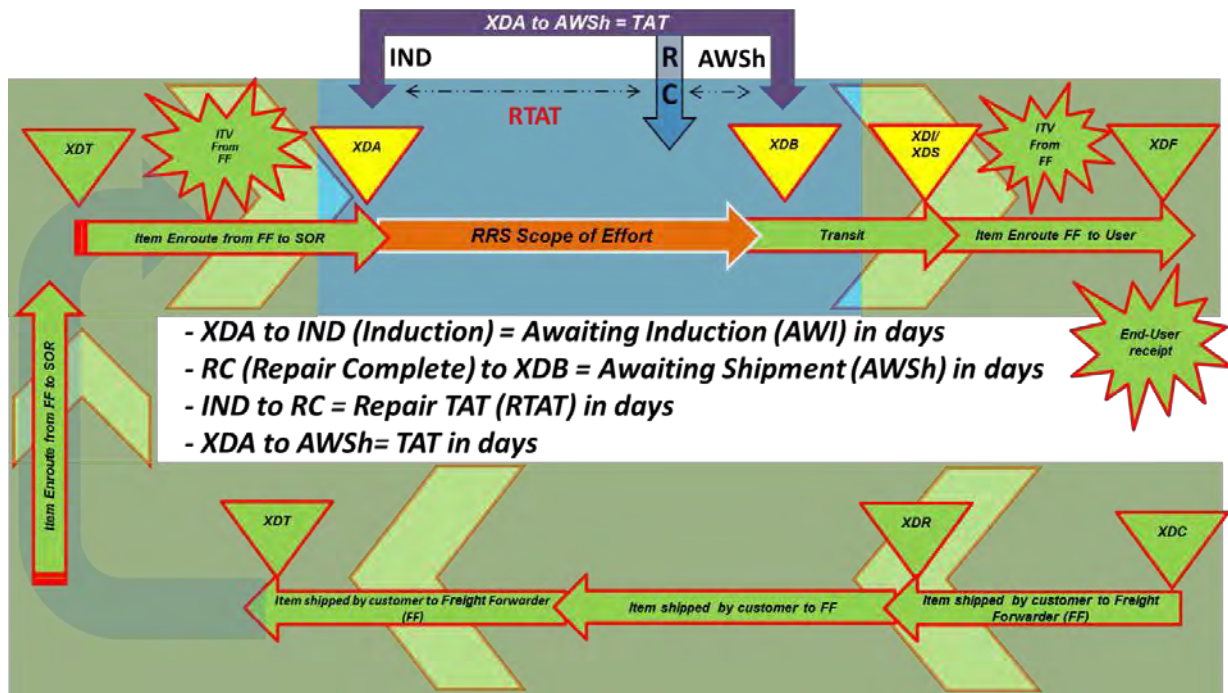


Figure 2 TAT Segment of End to End Supply Chain (RSAF F-15 Sustainment Lean Continuous Process Improvement, 2015)

Figure 2 reflects the FF and SOR uncontrollable transportation steps that can negatively affect the effectiveness of the F-15 parts repair and return supply chain. These segments of the supply chain are out of the direct control of the RSAF and United States Air Force supply chain managers, highlighting the need for improved asset visibility. XDC, XDR, XDT, XDA, XDB, XDS and XDF are the SAIMAS codes which are used by supply chain members to update the shipping status for parts in repair and return cycle. This figure represents the flow of parts in the supply chain from XDC, which means the part has been loaded into freight forwarder trucks in the depot and moved, to the XDF, meaning the parts have been repaired and returned to the depot. However, the potential for process improvement to shorten the end-to-end turnaround time and eliminate additional cost still exist, and is the main focus of future meetings of the supply chain managers (RSAF F-15 Sustainment Lean Continuous Process Improvement, 2015).

III. Methodology

Chapter Overview

This chapter explains the research methodology, the problem statement, hypothesis, research questions, and the importance of this thesis. In order to improve the performance of the RSAF supply enterprise, it is first important to define the problem. Through a qualitative study, this research will suggest the general problem, frame it with hypothesis and questions, and utilize previous RSAF / United States Air Force studies, data, and interviews, to identify enterprise level problems, recommend actions, and suggest additional research. The expected outcome will support the RSAF / United States Air Force continuous process improvement objectives for asset visibility, throughput, cost, inventory, and operational readiness.

Hypothesis

The research is focused at the enterprise level of supply chain performance, and is intended to set the stage for deeper studies. There are two principle hypotheses that provide framework for this study:

1. If excessive end-to-end flow times exist, the availability of reparable parts is negatively impacted.
2. If non-value queuing is identified and mitigated in the Royal Saudi Air Force supply chain enterprise, the flow time of repair and return of reparable items can be improved.

Factors evaluated in considering this hypothetical framework include, but are not limited to: batch processing, over processing, paper documentation/communication time, and repair budget authority/LOA line funding agreement issues.

Methodology

The aim of this study is to help managers at all levels of the F-15 parts repair and return supply chain in RSAF to identify and mitigate gaps and bottlenecks in their supply chains. The researcher faced difficulty in gathering information and data about the supply chain, as this research was not officially supported by RSAF. Fortunately, detailed information and studies were available through AFLCMC/WWQI, which is the United States Air Force program office for FMS support for Saudi Arabia. This field of research is new to the researcher; extensive time, consideration, and many meetings were necessary to understand how the F-15 repair and return supply chain works. The following are the steps done by the researcher to complete this research:

The first meeting was with Lt. Col. Hamblin (from the F-15 program office in WRAFB), Dr. Schultz, and the researcher at AFIT in the Center of Operational Analysis conference room. Lt. Col. Hamblin introduced the importance of this study, and how it impacts the supply process of the F15 parts in RSAF. He mentioned that the managers of the supply chain in the RSAF are concerned about the turn-around time in the SOR and this is what they believe is creating most of the delay.

The second meeting was held at Warner Robins AFB in the F-15 logistics office, with presence of Mr. Mueller and the researcher. In this meeting, the discussion was about the scope of the research and meeting with other experts in the program office. The researcher was able to meet the team officer B. Gen. Alatyah, who was in the area for an official meeting. Mr. Mueller explained in-depth about how the supply chain works, how parts move in each stage, and what previous studies have recommended for improvements. Also in this meeting, the main members of the supply chain were identified, to start the first draft of the supply chain mapping. The F-

15 program office provided extensive data for the supply process, from depot supplies in Saudi Arabia, to the SOR in the United States, and back to the depot again. This data provided useful details which were used in the research.

In the second meeting the team reviewed and agreed upon the enterprise level supply chain value stream map, including main members, organic and contractor provided repair sources, and documented gaps. Based on that, analysis of the supply chain and interviews were made to achieve a deeper understanding of the strength of the relationships among all members, and how they communicate with each other during supply chain activities. Also, the team considered the importance of including external factors affecting the supply chain, recognizing that such factors can also negatively affect the flow of parts in RSAF F-15 repair and return supply chain.

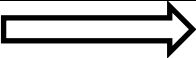
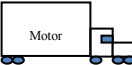
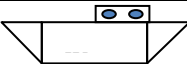
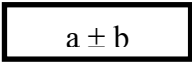
The first step in the analysis was an evaluation of the supply chain maps for the repair and return process. The flow of parts and methods of transportation represented the average flow time for the parts in each stage on the supply chain map. To build the supply chain map, the key supply node was identified as the depot supply located in the eastern region of the Saudi Arabia. Then, assessments were made of relationships between the depot supply and other key nodes of the supply chain, and those relationships were reflected in the supply chain value stream maps featuring detailed business process links.

The researcher needed to build two maps to compare the actual flow time of parts in the supply chain, with what processes owners expect from their process to perform. The first map is based on interviews and surveys and represents the expected performance based on processes owner's opinions. The second map is based on data analysis to represent mean flow time for each segment in the supply chain. Differences between actual flow time and expected

time identify what process(es) create delay in the supply chain, and then direct managers to manage those processes closely.

Table 1 shows what shapes mean in supply chain maps used in building the F-15 repair and return process.

Table 1 Shape descriptions of supply chain maps

Shape	Description
	Members of the supply chain.
	Non-managed relationships.
	Managed relationships.
	Monitored relationships.
	Non-member of the supply chain.
	Direction of parts flow.
	Ground transportation method.
	Air transportation method.
	Ocean transportation method.
	Latter a represent the mean flow time. b standard error.

For the second step, the researcher conducted interviews and surveyed various employees at different segments in the supply chain. The interviews and surveys were intended to help the researcher in understanding how parts flow in the supply chain. Also, the surveys were used to identify process owner's expectations about their processes, to compare them with actual flow performance. The resultant data supported assessments of relationships between members of the supply chain, as well as how they communicate with each other in the supply chain, and any impact of flow rates.

In the third step, the researcher received data sent from the RSAF headquarters about the supply chain. The received data set included thirty data points, with information about the repair process that could not be correlated with the other research data being used. As result that data was not used in the analysis of this supply chain study.

Next, the researcher received data from the F-15 program office in Warner Robins Air Force Base for the supply chain processes. Data shows the flow time of parts (in and out) for each stage, and the status of each part, i.e. repaired, condemned, work in process, on hold, return as is, etc... The data was organized in Microsoft Excel and statically analyzed by JMP[®] software. The data includes flow data for more than 11,300 part numbers. The data includes technical information which was more than necessary for the purpose of this research. The researcher edited the Microsoft Excel sheet to eliminate any parts with incomplete tracking data, or incomplete status (only repaired parts were used), and eliminated unneeded information for the remaining (> 5,000) parts data while keeping the flow (in and out dates) data. The following are the types of analysis done on the data

1. Statistical analysis was done by JMP[®] software using 300 random sample points from parts status data received from the F-15 program office in WRAFB, to build distribution for each stage, and take the mean flow time with the variation and confidence interval using type I error (α)= 0.05.
2. Statistical analysis on each SOR done using JMP[®] to assess the ability of the each repair source by taking the mean and 25 quartile, 75 quartile and 90 quartile using type I error (α)= 0.05 and compare their ability with the expected lead time in the contracts and agreements. Finally, represent the result of the statistical analysis in charts to better visualize how all SOR perform in comparison with what is written in

the contracts. Here is an example of one of the major companies used in the analysis and how statistical analyses were used to evaluate sources of repair.

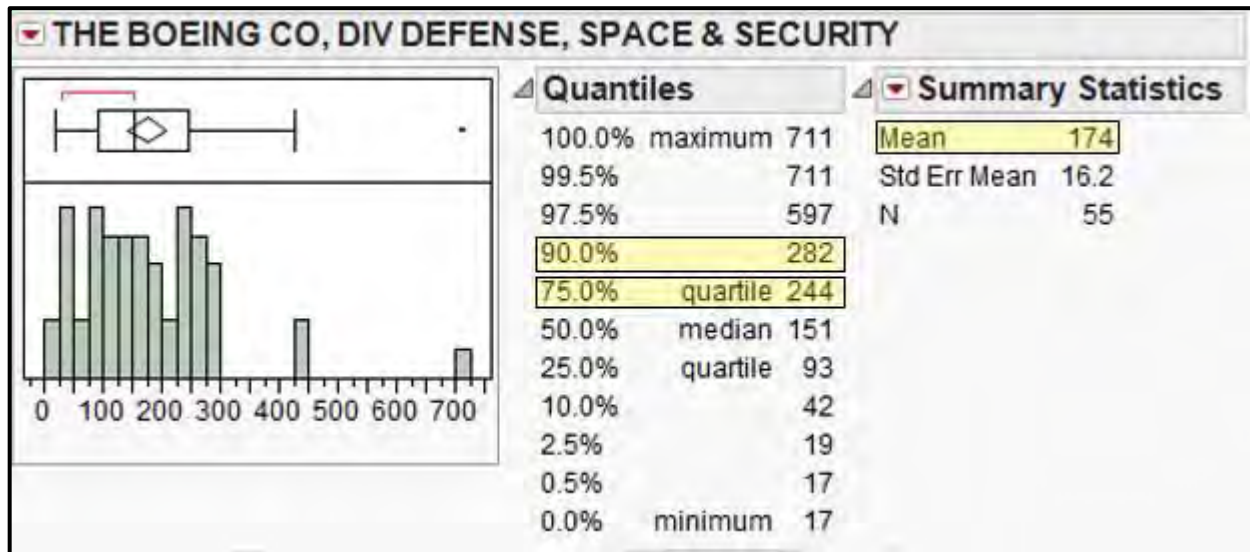


Figure 3 Statistical evaluation for source of repair

Figure 3 is an example of the statistical analysis for SOR. The mean repair time in The Boeing Co. DIV defense, space, and security highlighted under the summary statistics in figure 3, is 174.16 days. This means the average repair time at this SOR is 174.16 days, which exceeds the contracted time by 94 days. In the quantiles section shown in figure 3, the 75% quantile means that 25% of parts have been repaired in this SOR, the time taken to repair being equal to, or greater than, 244 days with a 164-day delay. And 90% highlighted under the quantiles section in figure 3, shows that the flow time of 10% of parts have been repaired in this SOR being equal to, or greater than, 282 days with a 202-day delay.

The same statistical analyses were done for more than forty SOR in the United States, and represent the mean 75% and 90% quartiles in charts to evaluate sources of repair performance.

The data provided by the F-15 program office didn't have the flow times for the maintenance squadrons, bases supply, and the depot supply. The data provided was only the average of the flow time for all processes within the RSAF boundaries. For that, the researcher conducted several interviews and surveys with at least two employees in each part of the enterprise process. Based on those interviews, the analysis of flow time in maintenance squadrons, bases supply, and depot supply were also done. The interviews and surveys were used to compare the results of the data, with what the process owner stated about their processes.

The interviews and surveys were written in Arabic and English languages. They were sent to the RSAF and FF employees in Arabic, and for SOR, the interviews were in English. The researcher sent the surveys to RSAF staff members, and to the repair and return prime contract by email, and started interviewing some employees by phone. All the surveys and interviews responses, either by phone interview or by the emails distributed to the RSAF staff, were collected and arranged.

The available data was analyzed by the researcher, with help from the research committee. Information was taken from the surveys and interviews that helped the researcher in validating the process flow map, and in making comparison between flow time of the mean actual flow time and the flow time that processes owners expected. Also, the evaluation of the surveys and interviews were used, to explain major findings that could possibly cause delay in any segment of the supply chain.

A process improvement expert was contacted and asked to suggest ways to improve the F-15 repair and return supply chain process. The idea of contacting a process improvement expert, instead of using the researcher's experience in Lean and process improvement, was to avoid bias in suggested fixes to the process. The process improvement expert was given the process flow map with information about how the process is performed. The process improvement expert gave his solution based on the available information.

The researcher applied the process improvement expert recommendations to the F-15 repair and return supply chain.

IV Analysis and Results

Chapter Overview

This chapter will contribute to a better understanding of how the RSAF supply chain works, and the level of efficiency in the supply chain. This chapter will also show the results of different analyses of available data, surveys, and interviews. Surveys were given to two employees in each stage of the supply chain inside the RSAF. The remaining stages of the supply chain were analyzed based on the data from the F-15 program office. The researcher also interviewed one of the specialists at Al Raha Group for Technical Services (RGTS), which is “the repair and return services prime contract”, and received useful data that contributed to this study.

Building Supply Chain Maps

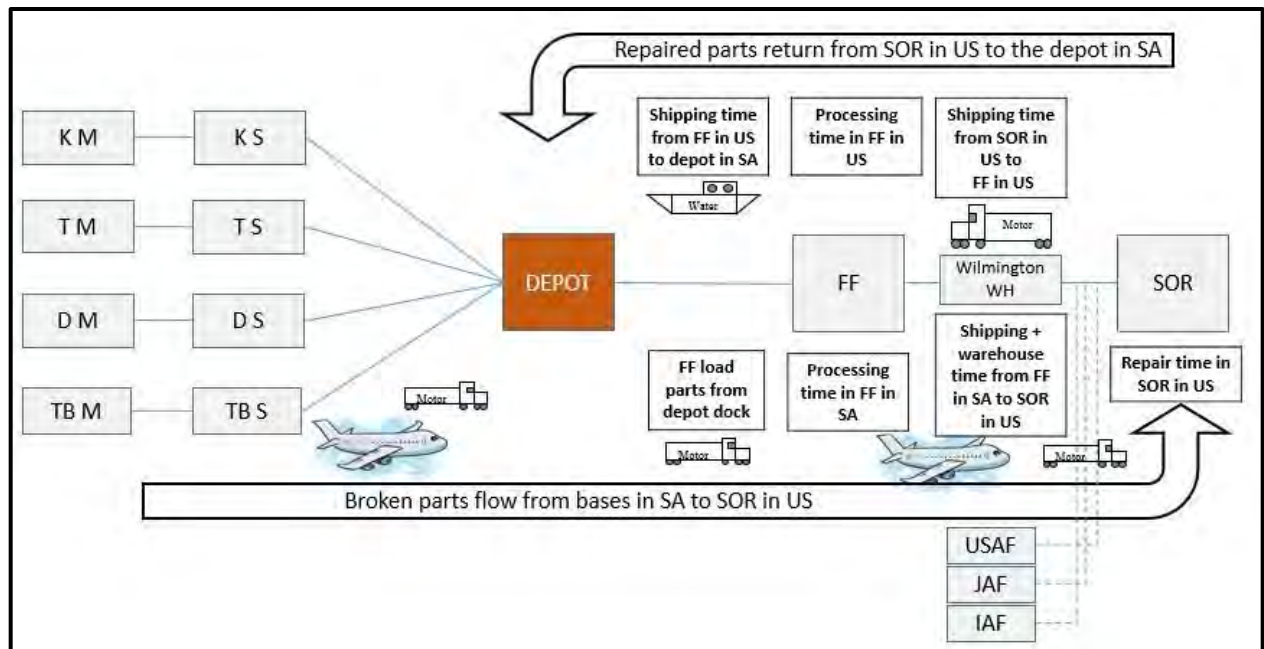
The first step in the analysis was building the supply chain map for the F15 repair and return process, based on the surveys and interviews with different process owners to document their observations on the process flow time. The process starts at the base, when the maintenance technician removes a broken part from the aircraft, then enters required information into the Royal Saudi Air Force supply chain tool, GOLDesp system, and completes needed documents for the base supply. At Base Supply, they complete the needed documents, update the status in the GOLDesp system, identify the priority, pack parts, and then ship the parts to the depot supply by air weekly or by a contracted truck shipping company. The depot then inspects documents to ensure they are properly completed, updates the status in the system, identifies the SOR, and checks fund status prior to preparing the parts for shipment.

The freight forwarder’s task is only to ship the parts to the repair source identified by the

depot supply. The repair addresses are maintained on the Master Item Repairable List (MIRL), which is jointly maintained by the RSAF and United States Air Force program office. RSAF C-130 and Saudia Airlines cargo services are used in air-shipping those parts to the United States. Then, parts are consolidated by the FF in the Wilmington warehouse, and shipped by trucks to the identified repair sources.

The RGTS is the prime contractor for managing repair services contracts with repair sources. Repair sources fix the parts and notify the FF, who consolidates the parts in Wilmington, and then ships them back to the depot with consumable parts shipped by air or surface, depending on the availability and priority.

This research is a broad view of the supply chain. The study will include only main members of the supply chain and will not analyze the deep details or processes inside the supply chain. The main members are Tabouk base maintenance squadron (TB M), Taif base maintenance squadron (T M), Kamis base maintenance squadron (K M) and Dahran base maintenance squadron (D M), Tabouk supply squadron (TB S), Taif supply squadron (T S), Kamis supply squadron (K S), Dahran supply squadron (D S), depot at Dahran airbase, freight forwarder (FF), and sources of repair (SOR). Given all the information, the supply chain is shown in Figure 4, where the focal firm is the depot supply. Also figure 4 shows non-members of the supply chain, whose repair requirement can affect the RSAF F-15 repair and return supply chain, as they use some of the repair sources. The non-members of the supply chain are the United States Air Force, Israel Air Force, and Japan Air Force, who operate the F-15 fighter aircraft.



The best supply chain scenario is when there are no errors or missing components, incomplete documentation, and parts and information flow smoothly throughout the supply chain. Parts need one day (on average) to be ready for shipment from base to the depot. Parts are shipped weekly from bases to the depot by C-130, except for Dahrhan airbase, where they send parts from bases to the depot daily by FF trucks. The depot needs an average of one week to make parts ready for shipment to SOR and the FF load containers from the depot docks. Shipment from Saudi Arabia to the United States is by air cargo and, after clearing customs, parts will be consolidated in the Wilmington warehouse, then distributed to different sources of repair. The FF requires one month to ship parts from depot to SOR, based on the judgment of experts in the program office.

In the contract of repair and return services, the prime contract of repair and return services guarantees to repair parts in fewer than 80 days, and then return them to

the FF for shipping back to the depot in Saudi Arabia. The data in this study includes longer repair and return flow times from earlier contracts. The current 14C contract is achieving turnaround time (TAT) of fewer than 65 days (Mueller, 2015). Usually, shipments are completed by ocean, along with consumables and other parts; however, urgent parts will be shipped by air. Ocean shipments usually need three-to-four weeks to clear customs and reach to the depot.

Given the information of the supply chain, Figure 5 represents the best end-to-end flow time that the supply chain must be able to repair and return parts. Based on surveys and interviews, the total time required is less than six months: approximately 153 days.

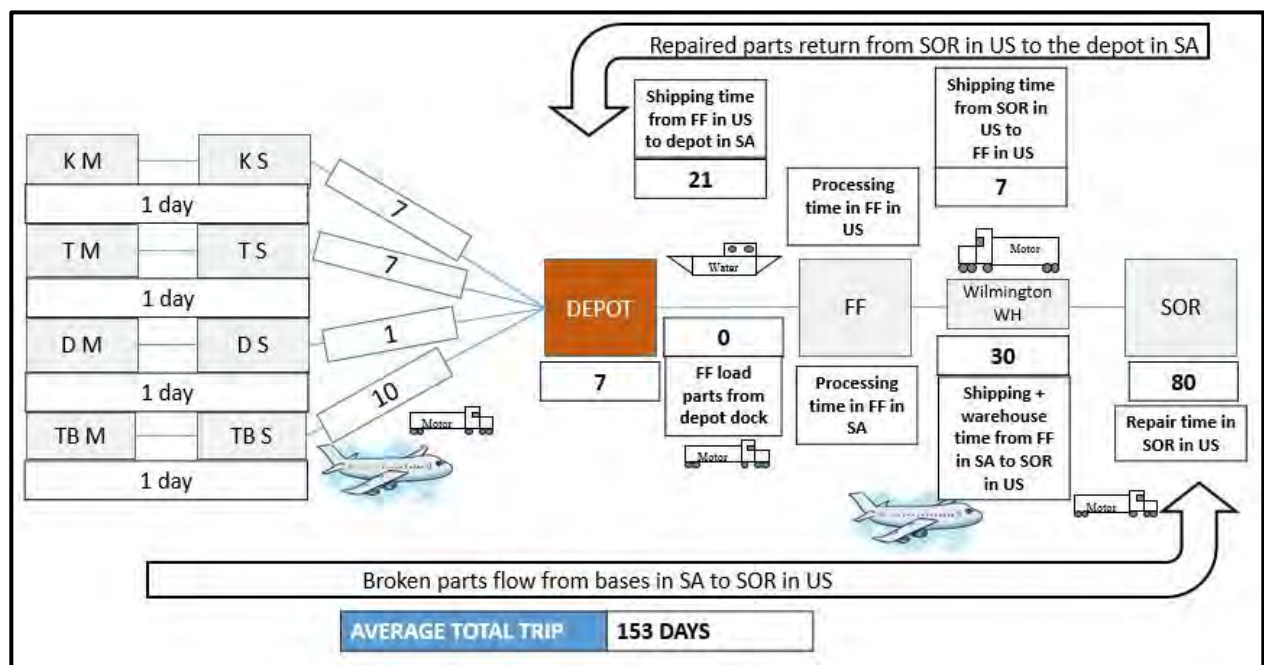


Figure 5 Ideal flow time expected by managers on interviews

Data Preparation

The program office provided SAMIS code data, which included more than 11,000 data points for the repair and return process, with different repair statuses. These data points were collected by the SAMIS coding system, which represents the status of parts in transit after parts have been shipped from depot, to return status at the depot. The researcher eliminated data with incomplete status i.e. WIP and on hold. 5081 data points were with complete status information. Figure 6 shows the percent of different product statuses for given data. 93% of the data was repaired by United States SOR, 4% were condemned, 2% returned as is, and 1% transferred.

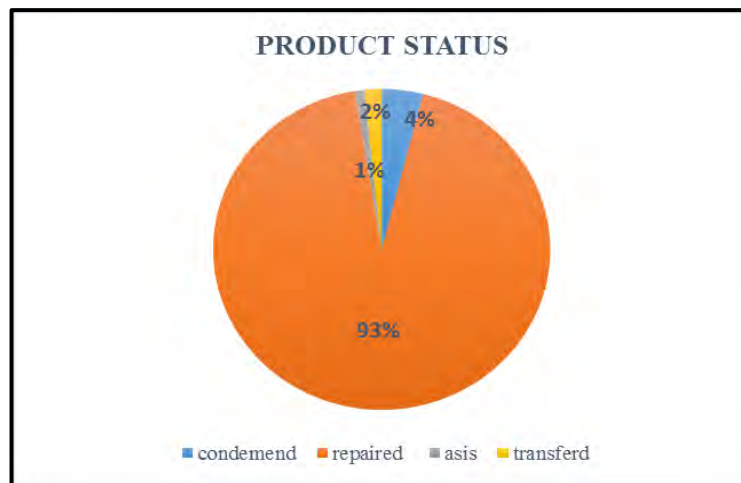


Figure 6 Product status

As this research is only about repair and return, the analysis used only data points which were repaired and returned to the depot. Table 2 was constructed from all available data (>5000 points) and shows the mean, maximum, and minimum flow time for repaired parts in every segment in the supply chain, from depot shipping time, to the time they were received in the depot after been repaired. As there are zeros in the data received from the program office, minimum flow time in each segment will be represented by

unknown, because a zero-day flow time is impossible.

Table 2 Statistical mean, maximum and minimum for flow time

	time in FF	From FF to SOR	Time in SOR	From SOR to FF	Time in FF	From FF to D
MAX	405	1683	1054	369	150	641
MIN	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Mean	1	56	106	9	5	24

Evaluation of Data Findings

The results of the statistical analysis for the supply chain data clearly show there are gaps between the actual flow and the expected best flow. Figures 7, 8, 9, 10, 11, & 12 show the statistical data for the flow times regarding each segment in the supply chain. Only 300 sample points were randomly selected from the whole available data. Data includes information about the process when parts shipped from the depot, to the time it returned to the depot after being repaired.

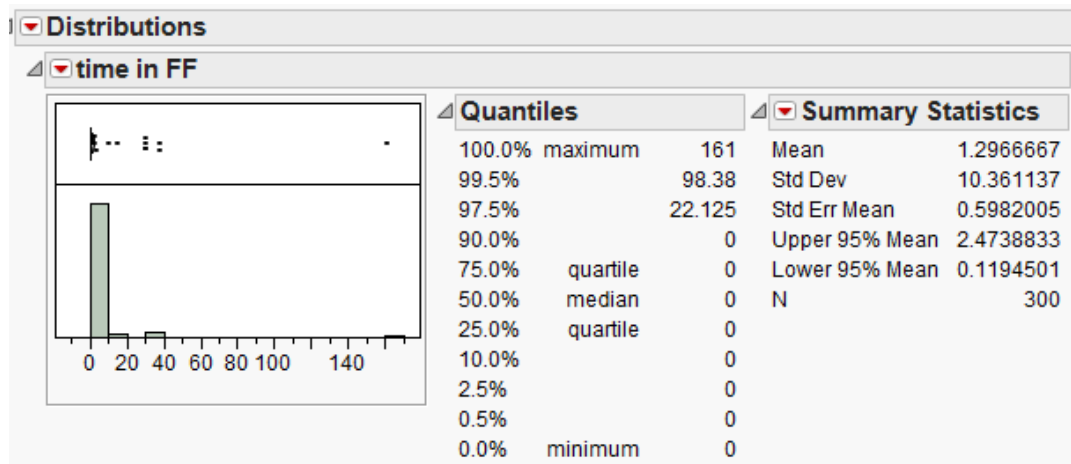


Figure 7 Statistical data for the flow time in FF

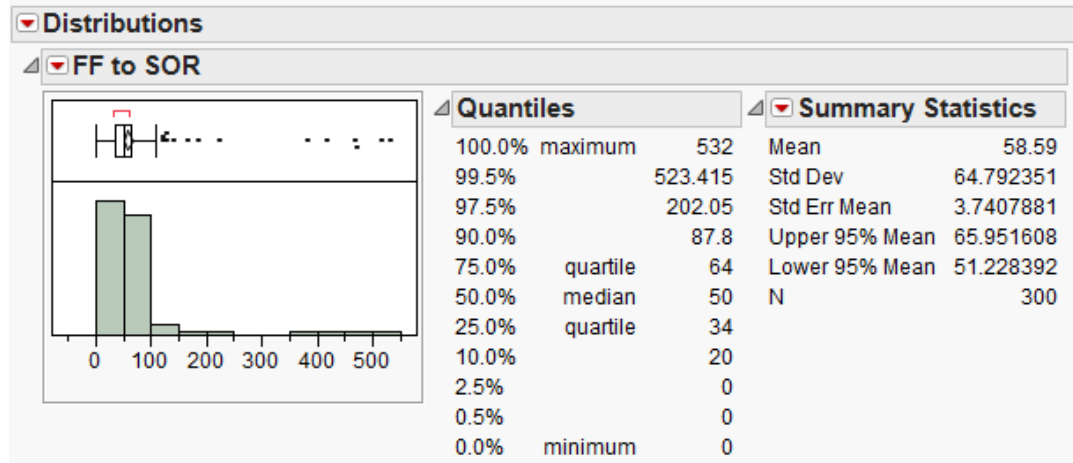


Figure 8 Statistical data for shipping time to US SOR

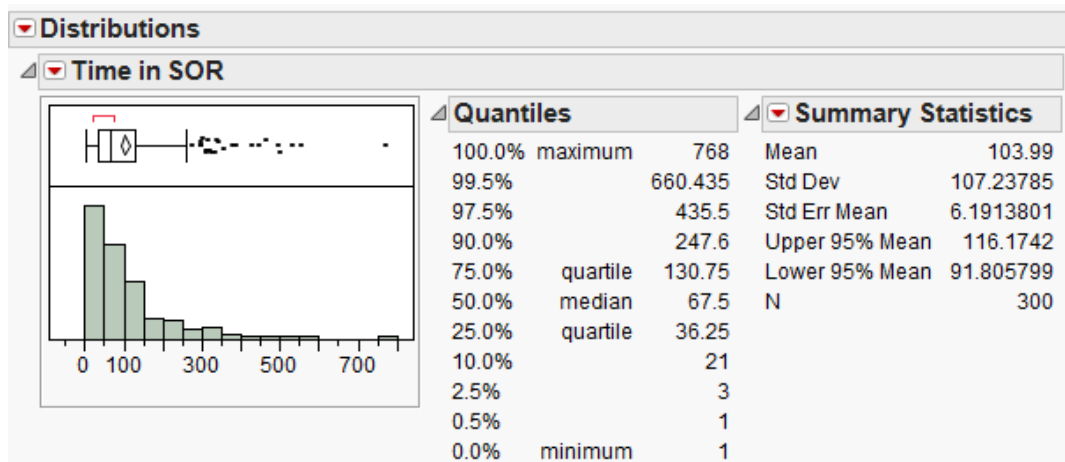


Figure 9 Statistical data for the flow time in SOR

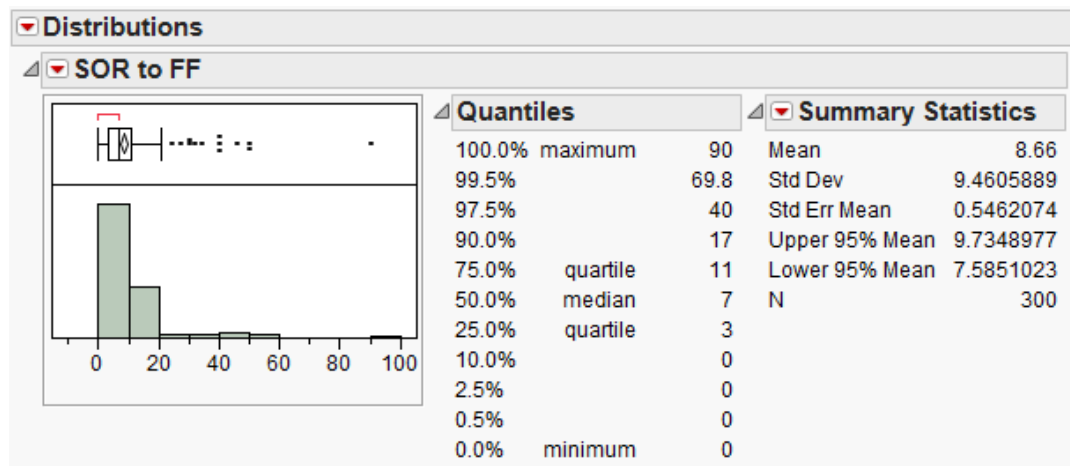


Figure 10 Statistical data for shipping time from SOR to FF

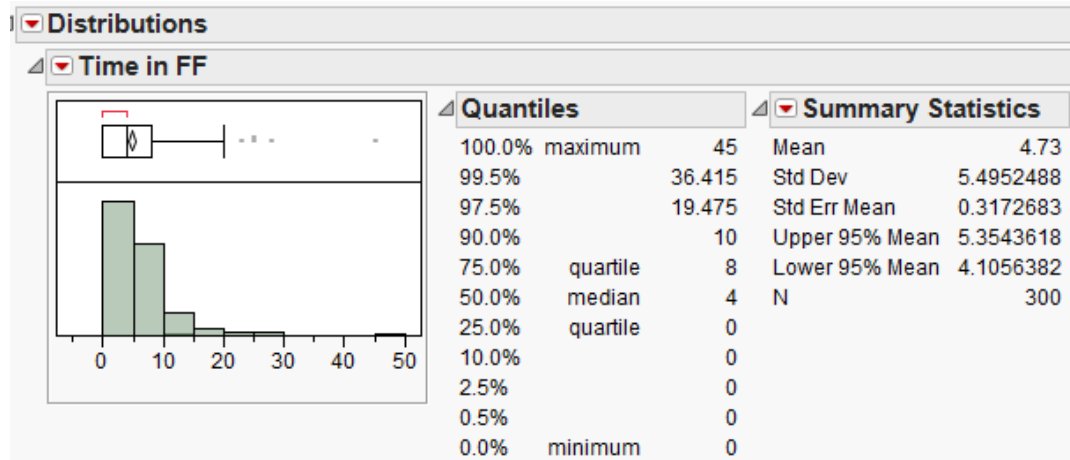


Figure 11 Statistical data for the flow time in FF

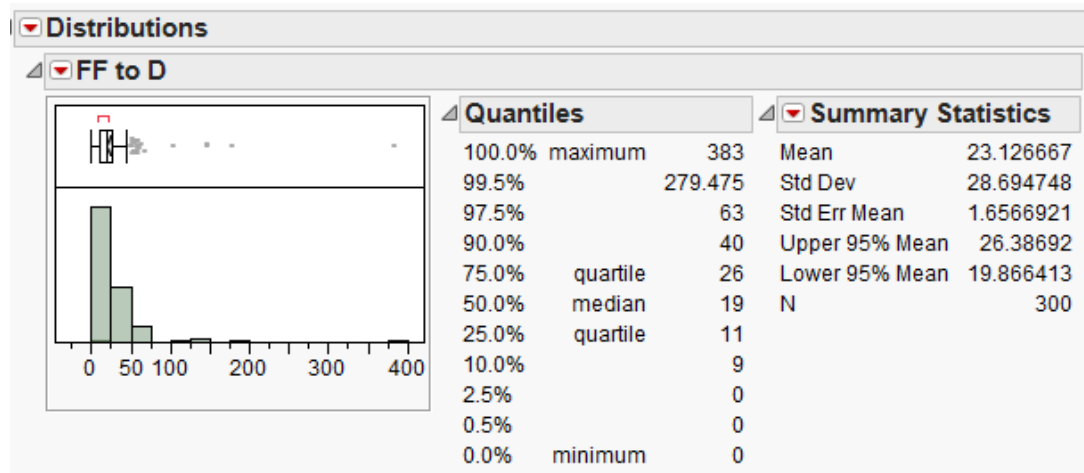


Figure 12 Statistical data for shipping time from US to depot

The data points, from before the parts have been shipped from the depot, are based on 350 tags. 350 tags will be attached to any part removed from an aircraft, whether it is serviceable or not. The researcher obtained the average flow time for the process from the time parts were removed from aircraft to the time parts shipped from depot, as shown in Table 3.

Table 3 Average flow time for the process before shipping from depot

	PHASE DURATION AVERAGES
From	350 Date Removed
To	XDC (Left Depot)
Average	183.68

(source: (Mueller, 2015))

Based on analysis results, the supply chain map can be represented, as in Figure 13, where the numbers are the mean flow time for each segment. The data below each segment represents the flow time for broken parts in transit to SOR. Data above each segment represents the flow time of repaired parts returning to the depot supply in Saudi Arabia. Highlighted times are flow times, which exceeded the expectations of processes owners, and created a delay in the supply chain.

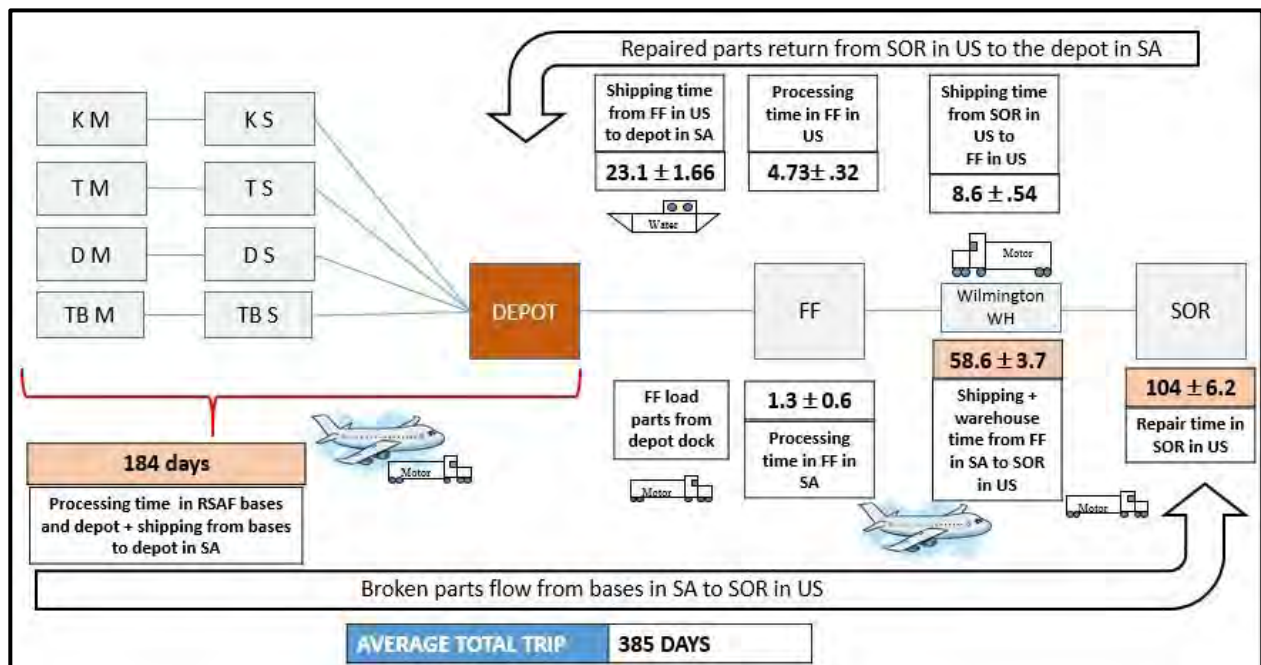


Figure 13 Mean time for the actual flow time in the SC

Evaluation of Gap Analysis

Table 4 Comparison of expected and actual processing/shipping time

	Maint. to depot	FF shipping	SOR repair time	SOR to FF	FF to depot shipping time	total trip
Expected processing/shipping time in days	15	30	80	7	21	153
Mean of actual processing/shipping time in days	184	58.6	104 Note 1	8.6	23.1	378.3
Gap	169	28.6	24	1.6	2.1	225.3

Note 1: This flow time is based on prior contract performance. Current 14C contract mean is under 65 days
(Mueller, 2015)

By comparing the best flow time expected by the process owner in each segment with actual flow time, gaps can be identified. The first gap is the processing and shipping time for the RSAF. The difference between actual flow time and best flow time is approximately $(184 - (1+7+7)) = 169$ days. That is a great gap in the supply chain that needs management solutions, to eliminate waste and reduce parts' flow time between bases and depot.

The second gap is the shipping time from depot to the SOR completed by FF. The difference between best flow time and actual time is about $(59 - 30) = 29$ days. Parts take double the time expected to ship from the depot in Saudi Arabia to sources of repair in the United States.

The third gap is the repair time in SOR. Repair sources are managed by the repair and return services prime contract, RGTS, who is contracted with more than 40 SOR in the United States to perform repair for the RSAF F-15 parts. Rapier sources repair for more than 3,000

national stock numbers (NSN) a year. Approximately 60% of parts are considered low occurrence rate, with short customer waiting time; approximately 30% of parts have a high occurrence rate with long customer wait times. The next figures show the statistical evaluation for most of sources of repair flow time; the red line is the limit time provided by the contract for sources of repair to return parts after been processed. (It should be noted that thanks to performance enhancement features added to the current 14C contract, the mean TAT is now under 65 days. (Mueller, 2015))

Figure 14 shows source of repair name in the horizontal axis and the 90% quartile of the repair time for that source of repair; this means the SOR can perform 90% of repairs in time equal to, or less than, the time shown above the blue line. The stated contract goal is to repair all parts within 80 days. Figure 14 shows that only 5% of the repair sources can complete 90% of their repairs in 80 days or less.

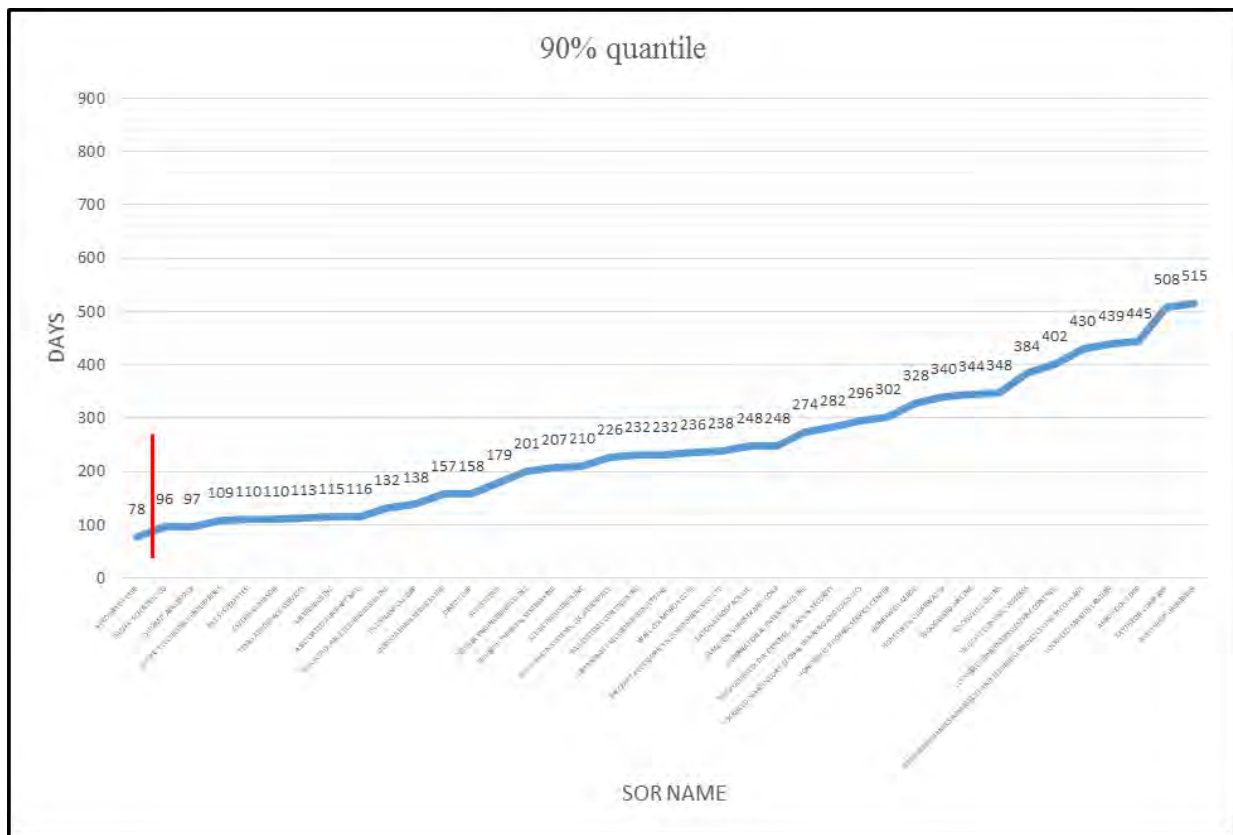


Figure 14 90 quartile for SOR flow time

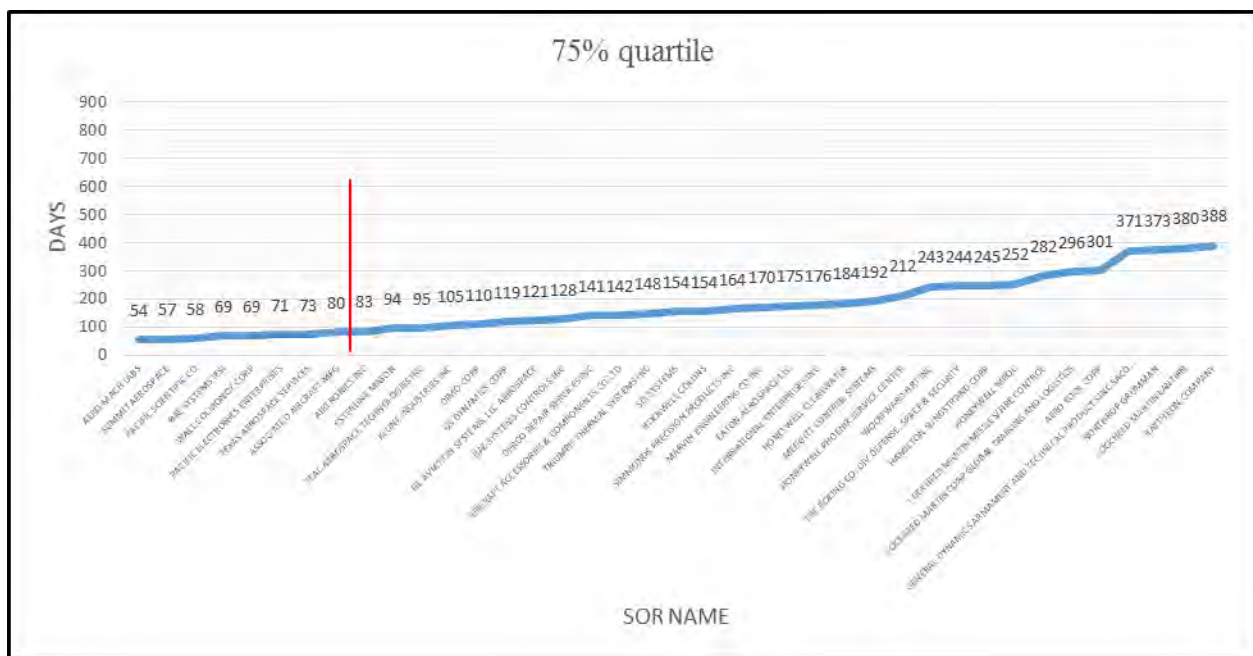


Figure 15 75% quartile for SOR flow time

Figure 15 shows source of repair name in the horizontal axis and the 75% quartile for repair time in that SOR which means that SOR can complete 75% of repairs in time equal to, or less than, the shown time above the blue line, which means that only 22% of repair sources can complete 75% of the repair in 80 days or less. That is one of the gaps in the supply chain, as 25% of repairs have delay problems - i.e. if 1,000 parts were sent to SOR, then 250 parts will be expected to have flow time longer than 80 days.

Figure 16 shows source of repair name in the horizontal axis and the mean flow of the repair time in that SOR, which means that only 32% of repair sources have 80 days or less as mean repair time.

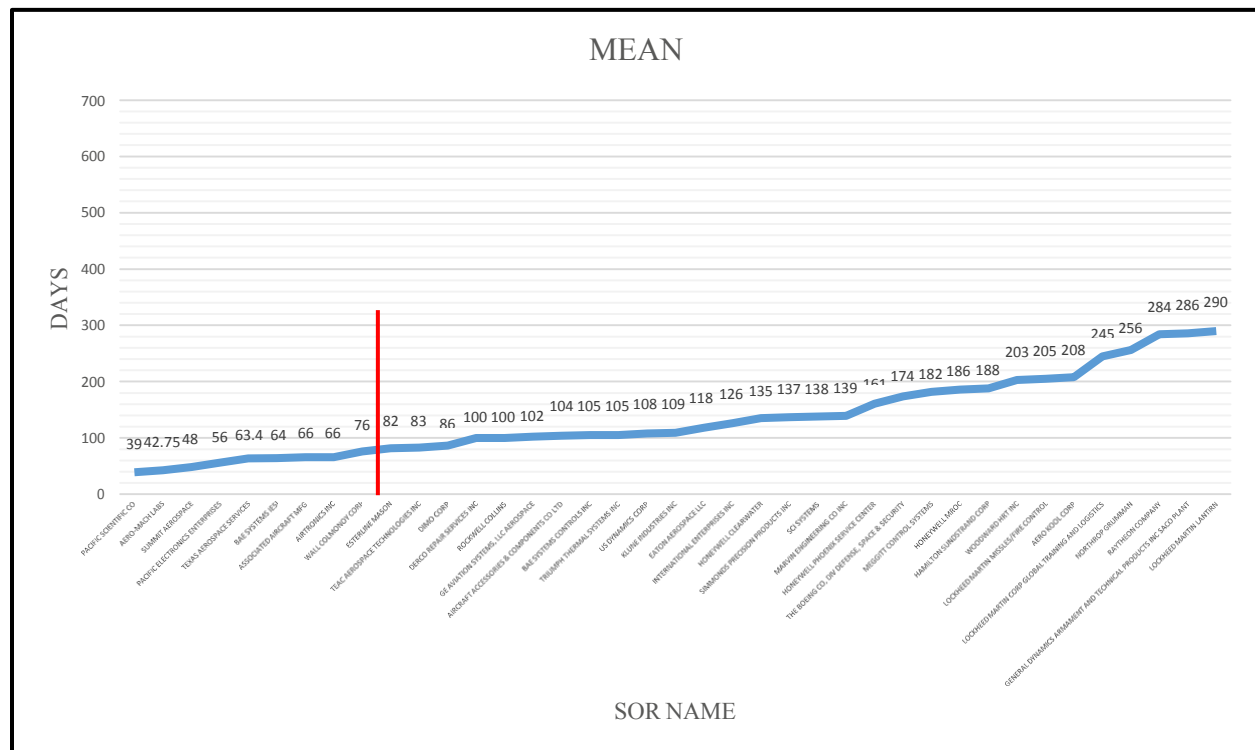


Figure 16 The mean flow time of SOR

The variation in the repair time is one of the gaps in the supply chain. The prime contractor of repair and return services should evaluate sources of repair, and apply the incentive and remedy recommendation of the program office which applies to their contract. Flowing down incentives will help encourage SOR to perform, as they will be paid fully-negotiated target fees if they perform repairs in fewer than 80 days. SOR who fail to repair parts in fewer than 80 days will not be paid their full fee. As Mr. Mueller from the F-15 program office explained in his interview, “Sources of repair performance improved when they were incentivized”. The incentive curve recommended is now part of the repair and return services’ 14C contract and is shown in Appendix G.

It is recommended that the RSAF and United States Air Force managers of the F-15 supply chain identify gaps that exist in the trip from base level to repair source and, to a lesser extent, in the return trip to the depot supply. Processes at the RSAF bases and end-to-end have been mapped by the program office, and many opportunities to eliminate waste were identified. Following the guidance of B. Gen Al Atyah, managers should continue to apply Lean management methods to eliminate those processes which only create delay with no value added.

Evaluation of Surveys and Interview Findings

Surveys and interviews with experts identified in Chapter Three offer explanations for the existence of gaps inside the supply chain. There are major findings of “waste” which, when eliminated, can repair the supply chain, and make it more efficient in delivering repaired parts in shorter flow time. Those gaps can be defined as waste, and can be eliminated through the application of Lean methods. The types of waste observed in the

supply chain are waiting due to slow flow of information, batching, requirement of special packing, and a lack of an overall asset visibility and tracking system. Delays are also being incurred due to documentation errors, missing components of parts, and putting broken parts on the shelf instead of shipping them for repair.

The following are findings and recommendations resulting from this study. Additional research is required for deeper studies to evaluate each segment individually. Each one of these findings is a limitation which constrains the speed of the flow in the supply chain. The delays can build, as the flow of parts faces more of these causes of delay.

1. Relationships

The working relationships of the supply chain managers (RSAF and United States Air Force) are vital to success. If relationships are poor between depot and different segments, delays and inaccuracy will result. Most of the supply chain members have weak relationships with its next member in the chain, and no relationships with their tier-two members.

Recommendations are to form cross-functional teams from the RSAF, United States Air Force/program office, and repair and return services prime contract to improve their relationship. Also, Lean and continuous process improvement initiatives should be continued, which would evaluate the supply chain performance during quarterly meetings.

2. Communication

The supply chain coordination flow of information is slow and is slowing parts flow as well. Currently, communication between members of the supply chain is through official letter, sent by regular mail, to resolve any issue. Delivery of these

letters, in a best case scenario, may take a week. As a result, delays occur if for any reason the flow of a part has been stopped--i.e. incomplete documents, missing components, etc.

As a recommendation, supply chain coordination should use secured email, fax, and phone to accelerate communication. In addition, points of contact (POC) in the RSAF/directorate of supply, and in United States Air Force Program Office, should be assigned for daily performance tracking and to solve any issue in the shortest possible time.

3. Manual inventory management and shipping tracking

The inventory management system for different parts is completed manually, where the staff makes the manifests, checks stock numbers, enters parts data into the system, and performs other tasks manually. Most of the time waste is caused by that manual system, and tracking parts through the supply chain has the same problem. These manual system updates could be causing errors or missing information in the data needed for material management, as evidenced by the fact that the data examined in this study included about 5000 data points with incomplete information.

As a recommendation, RSAF needs to evaluate the possibility of establishing automated inventory and shipping systems, i.e., barcode scanners, electronic gates, or other systems that help move parts faster. If implemented, an automated inventory system will establish asset visibility, and provide complete tracking information for parts in the supply chain.

4. Fund Authorization

A constraint in the supply chain is non-availability of repair funding. In the letter of offer and acceptance LOA, the RSAF has funded repair activities according to

contracts, typically for five-year periods of performance. Based on the way the obligation authority for depot supply authorizing repairs is regulated (divided into equal dollar value for each period of time i.e. quarterly or monthly), when the allowed funding for the specified period is completely used up, the depot is not allowed to ship more parts to the SOR. Actually, the repair contracts are in place and funded per the LOA.

As a recommendation, RSAF should coordinate with the program office to allocate budget of repair according to the LOA, so that depot supply has the authority to ship parts based on the line funding. In using this method, close coordination between the RSAF and United States Air Force managers will ensure that expenditures are closely managed.

5. Batching

As a result of non-availability of funding, or waiting to fill shipping containers, parts can be batched in the depot or in the FF warehouses in Wilmington. When parts are delayed due to batching, they may exceed the repair rate capacity of the repair source, which contributes in delaying the repair of those parts beyond optimum repair TAT.

As a recommendation, the RSAF / United States Air Force/ repair and return services prime contract and FF managers should coordinate shipments of parts according the capacity of repair sources and forecasts, based on average demand rates that can be documented by Supply Support Personnel (SSP) United States government contractor supply technicians. This can be accomplished by establishing points of contact, who coordinate during SAMIS DCN assignment, and “pull” NSN that are below forecast demand rates. Using this method will increase parts’ movement throughout the supply chain.

6. Lack of Urgency

There are many cases when unserviceable parts are shipped due to a lack of urgency on the part of the supply or maintenance staff, who may not feel that it is necessary to ship parts as soon as it has been tagged as unserviceable. That delay can be one reason of batching and other problems.

As a recommendation, use “carrot and stick” management to make the staff help in reducing parts’ flow time and develop analytics to measure and report flow times. This will encourage higher performance and improved flow times.

7. Special Packing Requirements

There are parts which require special packing or special containers; these special containers may not be available at the base supply level. So, parts which need special containers must remain until communication between members of supply chain to request that special containers is performed. Then, parts ship to the next levels in the supply chain.

As a recommendation, the RSAF needs to forecast for special packing requirements, and fill the demand of each base based on the forecasted demand. The creation of a “reusable container program,” and tracking containers, will resolve this problem and end delays caused by special packing

8. Missing Components

In some cases, “five times in last quarter” (Appendix F), parts have been shipped to repair sources with missing components. Those parts will not be repaired until missing components are received. In some of the cases where components are not found, the

repairs will be on hold awaiting managerial decisions through official letters between the United States government Program Office and the RSAF headquarters.

As a recommendation, turn-in procedures can be improved through better training for maintenance and supply staff to ensure each component is in its place after inspections, and before shipping to next member in the supply chain.

9. Wrong Addresses of SOR

In several cases, the address of the repair source in the attached tags and documentations is wrong. In that case, parts had to be sent from the wrong source of repair to the right source of repair--creating delays and second-destination shipping costs.

As a recommendation, active coordination and updates to the master reparable item list should become an ongoing process. The depot supply should constantly coordinate with the United States government program office to ensure master reparable item list accuracy. Depot supply should also coordinate with the repair and return services prime contractor during the DCN assignment process for address accuracy and for capacity planning. Any changes to the repair source addresses should be coordinated with the repair and return services prime contractor.

10. Poor Descriptions of the Problems

If attached documents cannot explain the actual component problem with parts needing to be repaired, then SOR require additional time to test those parts to identify what need to be repaired. This is an additional task for SOR, costing time and money, and can be avoided if part discrepancies are clearly explained by the maintenance staff at the base level.

As recommendation, better training is needed for maintenance staff to explain problems perfectly in order to save time and resources.

11. Over-Processing

Previous studies conducted by the United States government program office have produced value stream maps. Those maps show the process in each stage of the RSAF base and depot levels. There are processes at the base level that overlap with processes at the depot level. This problem is called “over processing.”

As a recommendation, the RSAF needs to continue past Lean efforts to include maintenance, supply, and depot employees, to identify overlapped processes and eliminate them.

Recommendation for Future Research

The RSAF headquarters Chief of Supply and the United States program office should sponsor further research into the development of additional SOR in the Saudi Arabia, at least for the 1000 national stock numbers which have regular demand occurrence rates, in order to reduce or eliminate overseas shipping time. The examination of expansion in Saudi Arabia’s repair sector must include the identification of items for which the RSAF and United States government have data rights needed to complete repairs. In addition, the research should address the supply chain and component parts vendors that would support repair within Saudi Arabia, with emphasis on the impact of export licensing and individual component pipeline time. This future study could shorten support times for some of the frequently used items, and optimize others that still must be repaired internationally. A list of all recommendations is presented in Appendix H.

V. Conclusion

Chapter Overview

This chapter: summarizes results and recommendations discovered while completing the analysis of the RSAF supply chain, concludes interviews, evaluation of existing supply chain data, and interviews with participants in the supply chain from base level to the United States government program office and repair and return services prime contractor.

Research Conclusions

This thesis has mapped and defined the boundaries of the RSAF F-15 repair and return supply chain, including main members of the supply chain. The findings of this study suggest ways for RSAF and United States Air Force managers of the F-15 repair and return supply chain to eliminate time waste, which will improve the end-to-end turnaround time of the repair and return process.

This study used supply chain mapping and Lean to explore if time can be saved during the F-15 repair and return supply chain. Supply chain mapping and Lean made it possible to discover areas to improve a process of the supply chain. Using Lean, supply chain mapping and gap analysis made it possible to compare the results of actual and best case flow times. Supply chain mapping and Lean also provided the possibility to use quantifiable metrics, which made the process easier to understand, and provided process improvement recommendations.

While gathering information for the thesis, it became clear that relationships, communication (including asset visibility) between the RSAF headquarters, depot supply, the United States government program office, RGTS (the RRSs prime contract), and the bases,

can be improved. Communication, asset visibility, or “flow of information,” is the biggest gap in the F-15 repair and return supply chain.

All interviewed individuals agreed that the F-15 end-to-end repair and return supply chain can be improved. The majority of respondents agreed that there are unnecessary or wasteful steps that should be eliminated. Supply chain mapping and Lean are designed to identify and eliminate any waste in the supply chains. In fact, most waste lies under hidden processes, which were identified in this thesis.

From given data and collected information, the F-15 repair and return processes in the RSAF take a lot of time to ship, repair, and return parts, compared with the capabilities of the supply chain. Excessive time spent in the process results in reducing the operational capability of the RSAF. This delay in the supply chain also leads to additional costs for new parts to recover non-availability of needed parts in supply shelves to meet the operational requirements.

Lean considers waiting time, and unnecessary or extra movement, as waste that should be eliminated. The F-15 repair and return supply chain uses a lot of time in communication, batching, manual inventory, mistakes, and over-processing. This thesis concludes all of the wastes can be eliminated or reduced by applying Lean.

Significance of the Research

The RSAF and United States government program office started end-to-end supply chain mapping as a result of the initiative of the RSAF headquarter’s Chief of Supply. This thesis is the first attempt to perform detailed mapping and analyses of one of many supply chains for the RSAF, which is the next essential step in improving supply chain performance. The RSAF

suffered for decades from non-availability of needed parts on supply shelves, due to long lead times of repair and return process. This research presents the main causes of the long customer waiting time for the F-15 repair and return supply chain, and paves the way for deeper studies to identify waste inside each segment of the supply chain. The process of repairing and returning parts to the supply shelves can be improved, and lead times shortened, by eliminating the negative effects of the findings presented in Chapter Four in this thesis. Enhancing relationships between members of the supply chain, as well as using new communication and automated inventory and shipping tracking systems, presents the greatest opportunities to improve the supply chain and reach higher aircraft readiness.

Research Limitations

This study is only a theoretical study. It has not yet been applied to the RSAF F-15 repair and return process. It should also be noted that the researcher did not conduct the thesis and data collection in Saudi Arabia - increasing the difficulty in gathering additional data regarding each segment in the supply chain.

Recommendations for Action

1. Forming cross-functional RSAF / United States Air Force teams to continue Lean/continuous process improvements initiatives to complete efforts and improve performance.
2. Increase communication/focus with quarterly RSAF / United States Air Force Performance Reviews that include key inventory issues such as replenishment spares and sources of repair capacity planning.

3. Assigned Point of Contact for daily performance tracking, RSAF directorate of supply Analysis Section and the Program Office Operations & Analysis Section.
4. Evaluate contract with repair sources and review performance continuously.

Recommendation for Future Research

Support further research focused on more detailed improvements to supply chain processes in deeper and more narrowly-focused studies, and evaluate opportunities of Saudi Arabian repair.

Summary

This research analyzed supply chain mapping, as well as Lean and gap analysis, to identify factors that impact flow times causing delays in the RSAF F-15 reparable parts supply chain. Gaps identified are in RSAF level, and in transportation of broken parts to repair sources and repair time. The supply chain met expectations of process owners in the return of parts after they were repaired. The main causes of delay identified in this thesis are relationships, communication, and inventory management processes. RSAF and United States Air Force managers of the supply chain are recommended to improve their relationship with other members of the supply chain, improve communication methods and inventory management systems, and continue ongoing initiatives of process improvement. These process improvement efforts should include members and process owners of the supply chain at all levels, and feature performance analytics and regular RSAF/ United States Air Force performance reviews.

Appendix A

Survey number: 1

Maintenance: (after removing it from the aircraft)

1. What are the steps need to be done and documents to be filled required to submit parts to the base supply?

Fill 350 tag and 10-3 form and enter status data into GOLD system

2. How long is the flow time the process from uninstalling any part from the aircraft to submitting it to the base supply? Estimate percentage of normal flow.

About five to six hours

3. In best case; how long it takes? Estimate percentage of best flow.

Three hours

4. Sometimes problems disturb the flow and make the flow time longer. What are major problems that when they occur make flow time longer or create some delay? Estimate the percentage

- Problem1: special container requirement

What actions need to solve the problem and how long it takes?

Waiting to receive needed container

5. To what extent can you track the part in the supply chain?

Base supply

6. How do you communicate with base supply, depot, FF & SOR?

Through MSL “maintenance supply lesion office”

7. How do you assess the relationship b/w maintenance and supply squadrons and with depot supply?

No relationship

Appendix B

Survey number: 2

Base supply:

1. What are the steps need to be done and documents to be filled required to send parts to the depot supply?
Check and update tags, documents and GOLD status. Place parts in shipping area
2. How often parts shipped to depot supply (is it scheduled shipment?) and what is the transportation method used?
Weekly by C-130 and daily if needed, daily in Dahrhan airbase
3. How long it takes normally to make a broken part ready to be shipped to the depot supply? Estimate percentage of normal flow.
One shift "eight hours"
4. In best case; how long it takes? Estimate percentage of best flow.
Three to five hours
5. Sometimes problems disturb the flow and make the flow time longer. What are major problems that when they occur make flow time longer or create some delay? Estimate the percentage
 - Problem1: GOLD system problems i.e. system down.
What actions need to solve the problem and how long it takes?
Wait till problem fixed
 - Problem2: Special container requirement
Actions, time? Wait to receive needed container
6. To what extent can you track the part in the supply chain?
To depot supply
7. How do you communicate with maintenance, depot, FF & SOR?
Through MSL with maintenance, mail with depot supply, FF N/A, SOR N/A
8. How do you assess the relationship b/w supply and maintenance squadrons and with depot supply?
Weak if it is there.

Appendix C

Survey number: 3

Depot Supply: Repair & return only

1. What is the transportation method used to send parts to FF? And is it scheduled in a daily shipment or weekly or monthly? Or on what bases does depot send parts to FF?

By FF trucks in depot, if there is enough fund in SOR, shipment will not wait

2. What is the processing time for parts to be ready for shipping?

Average of 72 hours

3. How long is the flow time normally for parts since it enter depot till received by FF? Estimate percentage of normal flow.

It depend on the need, if the spare is needed urgently then it will take 7 days

4. In best case; how long is the flow time? Estimate percentage of best flow.

Three to six days

5. Sometimes problems disturb the flow and make the flow time longer. What are major problems that when they occur make flow time longer or create some delay? Estimate the percentage

- Problem1: fund constrains
- What actions need to solve the problem and how long it takes?

3-6 Months, nothing except to speed up the signing of the repair contract

6. To what extent can you track the part in the supply chain?

Complete tracking (the reparable spares are tracked by serial number)

7. How do you communicate with? Maintenance & base supply (mail), FF (officially through depot commander) & SOR (officially through the program office)

8. How do you assess the relationship b/w

- Depot supply and FF (poor).
- SOR (weak through program office)

Appendix D

Survey number: 4

Freight forwarder: Repair & return only

1. Where is the location FF receive parts from depot?
In the depot docks
2. What is the percent of parts that will be sent for the repair in United States out of all received parts?
100%
3. How frequently FF received parts from depot supply?
Truck every 4-5 days
4. What are documents need to be filled required to send parts to the SOR?
Shipping manifest, Certificate of country origin, repair order
5. How often parts shipped to SOR (is it scheduled shipment?) and what is the transportation method used?
Every month by C-130, or by Saudia air cargo if necessary.
6. Sometimes problems disturb the flow and make the flow time longer. What are major problems that when they occur make flow time longer or create some delay? Estimate the percentage
When SOR not authorized due non fund, the parts will be hold in Wilmington till SOR is authorized,
7. To what extent can you track the part in the supply chain?
From depot to SOR
8. How do you communicate with?
 - Depot (direct by official letter)
 - SOR (N/A)
9. How do you assess the relationship b/w
 - FF and SORs (N/A)
 - FF and depot supply (Weak if it is there)?

Appendix E

Survey number: 5

Freight forwarder :(after parts been repaired)

1. What are the steps need to be done and documents to be filled required to return parts to the depot?

None. Same documents will be attached already with repaired parts.

2. How often parts shipped to depot (is it scheduled shipment?) and what is the transportation method used?

No schedule

Urgent: by air, Normal: sea

3. How long it takes normally to return a repaired part to the depot? Estimate percentage of normal flow.

21 days.

4. In best case; how long it takes? Estimate percentage of best flow.

12- 15 days

5. Sometimes problems disturb the flow and make the flow time longer. What are major problems that when they occur make flow time longer or create some delay? Estimate the percentage

- Problem1: Utilization of C130 and container.

What actions need to solve the problem and how long it takes?

Wait to fill container.

6. How do you communicate with depot & SOR?

Letter

7. How do you assess the relationship b/w FF and SORs and with depot supply?

Weak

Appendix F

Survey number: 6

Source of Repair:

1. What are the priorities and policies to repair broken parts for aircrafts?
 - MICAPs
 - Quick fix (clean, align, calibrate, test)
 - AWP in order of the arrival of the needed parts
 - Parts requiring Engineering Disposition
2. What is the average processing time to repair parts?

80 days by contracts.
9. Sometimes problems create delays in the flow time. What are major problems in received parts that make flow time longer or create some delay? Estimate the percentage
 - Problem1: poor description of actual problems with parts

What actions need to solve the problem and how long it takes?

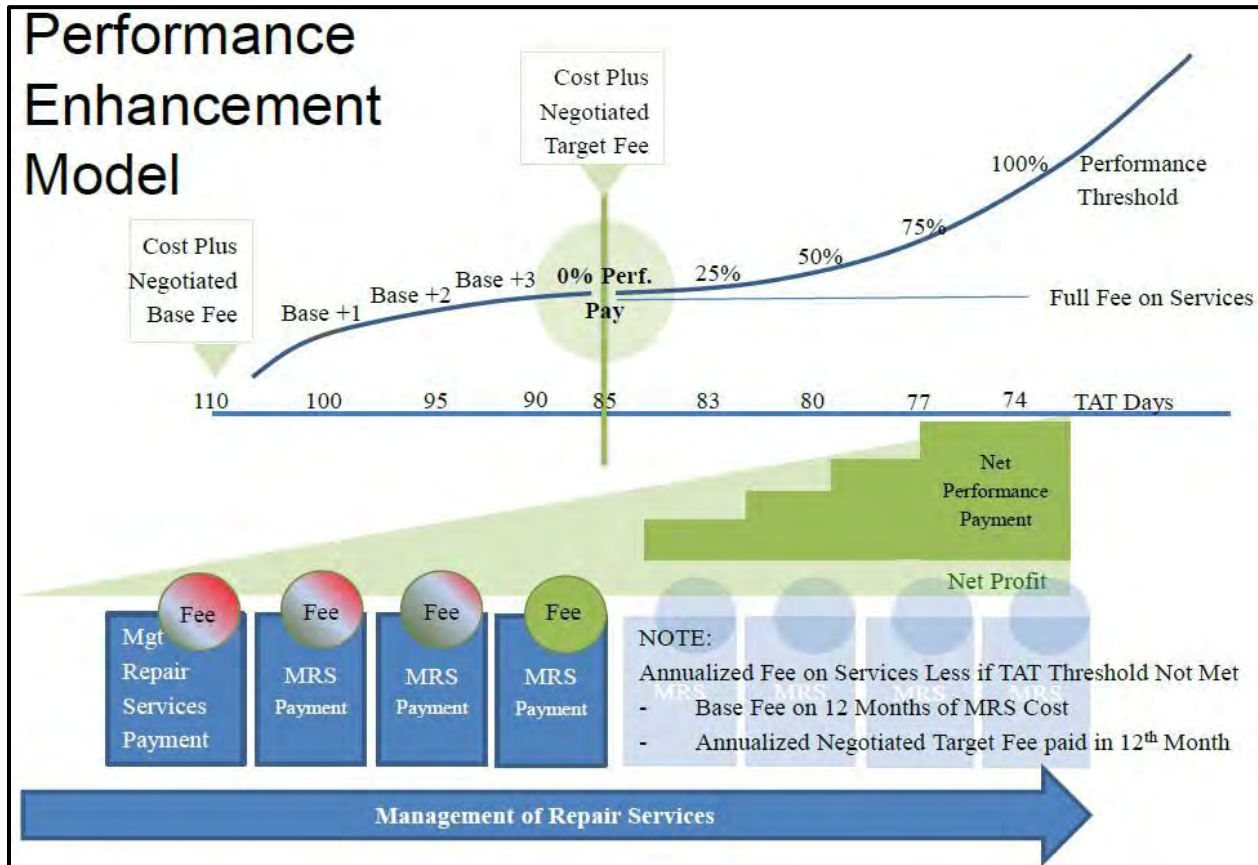
Inspection, run test then induct to repair.

 - Problem2: missing components inside parts (5 times last quarter)

Actions, time? Send letter to RSAF to inform and suggest action.
3. How do you communicate with depot and FF?
 - the program office, SOR, and FF are email and phone
 - with Depot Supply formal action is through letters (all letters must issue from the United States government Program Office)
4. How do you assess the relationship b/w SOR with depot supply?
 - SOR do not communicate with Depot Supply since they are contractually obligated only to the RRS prime contractor.

Appendix G

The incentive curve recommended by Mr. Kent Mueller from the United States government program office used to incentivize the R&R prime contractor in shortening repair flow times. This model is part of the current 14C RRS contract and has improved performance nearly 40% at a reduced cost.



The performance curve give SOR opportunities to get their negotiated revenue in full if they satisfy the requirement of the RSAF by delivering repair parts in less than 80 days. If SOR fail to repair parts in less than 80 days they will penalized by getting lower percentage of negotiated revenue.

Appendix H

List of recommendations:

1. Forming cross-functional Royal Saudi Air Force / United States Air Force team to continue Lean/continuous process improvements initiatives to complete efforts to improve performance.
2. Increase communication/focus with quarterly Royal Saudi Air Force / United States Air Force Performance Reviews that include key inventory issues like replenishment spares and sources of repair capacity planning.
3. Assigned Point of Contact for daily performance tracking, Royal Saudi Air Force directorate of supply Analysis Section and the Program Office Operations & Analysis Section. Create a “common view” of performance.
4. Evaluate contract with repair sources and review performance continuously.
5. Evaluate the possibility of establishing automated inventory and shipping systems i.e. barcode scanners or electronic gates or other systems that help to move parts faster.
6. Coordinate with the United States government program office to allocate budget of repair according to the LOA and to ensure MIRL accuracy, and coordinate with the repair and return services prime contractor during the DCN assignment process for address accuracy and for capacity planning.

Bibliography

Abudi, G. (2010, April 28). *Project Management Approach For Business Process Improvement*. Retrieved April 15, 2015, from The Project Management Hut: <http://www.pmhut.com/project-management-approach-for-business-process-improvement>

Anupindi, R., Chopra, S., Deshmukh, S. D., Van Mieghem, J. A., & Zemel, E. (2011). *Managing Business Process Flows*. Prentice Hall.

Bicheno, J., & Holweg, M. (2009). *The Lean Toolbox The Essential Guide To Lean Transformation*. Buckingham, England: PICSIE Books.

Flores, B. E., & Whybark, C. (1986). Multiple Criteria ABC Analysis. *International Journal of Operations & Production Management*, Vol. 6 Iss 3 pp. 38 - 46.

Gardner, J. T., & Cooper, M. C. (2003). Strategic Supply Chain Mapping Approaches. *Journal of Business Logistics*, Vol. 24, No.2 pp.37 - 64.

Keller, R. (2011, December 10). *It's the Process, Not the People*. Retrieved April 15, 2015, from industry week: <http://www.industryweek.com/workforce/its-process-not-people>

Lambert, D. M. (2014). *Supply Chain Management Processes, Partnerships, Performance*. Ponte Vedra Beach: Supply Chain Management Institute.

Mueller, K. A. (2015, June 1). Senior Principal Acquisition Analyst at F15 SA Program. (C. A. Alshehri, Interviewer)

(2015). *RSAF F-15 Sustainment LEAN Continuous Process Improvement*. Warner Robins.

Siha, S. M., & Saad, G. H. (2008). Business process improvement: empirical assessment and extensions. Vol. 14 Iss 6 pp. 778 – 802.

States, E. C. (2011). *Lean in Government Starter Kit*. Retrieved from <http://www.epa.gov/Lean/government/starterkit/resources/Lean-Starter-Kit.pdf>.

Womack, J. P. (2007). *The Machine That Change The World*. New York: Free press.

Womack, J. P., & Jones, D. T. (2003). *Lean Thinking Banish Waste and Create Wealth in Your Corporation*. New York: Free press.

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14. ABSTRACT This research focuses on improving the F-15 reparable parts supply chain process in the Royal Saudi Air Force. The F-15 reparable parts supply chain process currently requires too much time to repair and return parts which affect the capability of aircraft operational missions. Because the F-15 is the first line of Saudi Arabia's defense, it is essential that they be fully mission ready in the shortest time possible. That can be done by improving relationships, communication, reducing batching before shipments 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 F-15 supply chain. The selected techniques are supply chain mapping, Lean management approach and gap analysis. The research suggests that those techniques can improve the F-15 supply chain process in the Royal Saudi Air Force.				
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