INVESTIGATION ON AN AVIONICS PARTS DEFICIENCIES IN ROYAL SAUDI AIR FORCE FLEETS

THESIS

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Abstract

The Royal Saudi Air Force (RSAF) is experiencing a shortage in certain avionics parts due to a lack of reliability. This issue is causing a supply chain disturbance in the F1-15 fleet and the Hawk fleet. One of the factors behind this problem is the environmental effects in the kingdom of Saudi Arabia (KSA). In this research, a study will be provided to understand the causing factors and the solution to this issue. The study will investigate and analyze the methods for the Improvement Cycle Processes and the Quality Management within the RSAF repair cycle to help improve the system to eliminate failure of the parts. Data collection, surveys, and an Interview will be conducted from RSAF database and personnel to help understand the situation. The study will conclude that the environmental effects such as heat and dust are causing electronics parts failure in RSAF. From the finding, the discrepancies are rising during summer and fall time due to the environment change. Also, RSAF personals are causing some of the problems due to lack of training in the quality process and supply chain process. The study provided recommendations to improve the system and to raise the readiness in RSAF.

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To God, with whom all things are possible

To my Country

To my Parents

To my Lovely Wife

To my Kids

To my Brothers and Sisters

To my Best Friends

For their unwavering support

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Nasser S. Alanazi

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INVESTIGATION ON PARTS DEFICIENCIES IN ROYAL SAUDI AIRFORCE FLEETS

I. Introduction

1.1 Background

The Kingdom of Saudi Arabia (KSA) is among the top twenty economies in the world. Also, KSA has the second-largest petroleum reserves,and it is considering among the largest exporting countries of oil . KSA is a significant member of the Organization of Petroleum Exporting Countries (OPEC), who has a substantial influence on the prices of oil in the world. With every one of those reasons, KSA must maintain its security and safety by purchasing the necessary aircraft and equipment. KSA is one of the top buyers from the United States of America (USA) market. Also, KSA is buying a lot of weapons and parts from the United Kingdom (UK) and other European countries. This strategy of a wide range of coordinations sources is one of the grand plans for the future. Nearly 1000 aircrafts have created a demand for parts and repair stations, which has prompted import development in the KSA and will proceed for the following decades. USA produced military and civilian airplanes require parts for routine maintenance repair and overhaul activity, as Saudi Arabia operates large fleets of the F/15 model. Figure 1 illustrates the rank between the countries in the world with KSA , with 3.2% of military expenditures in the world for 2019.

Royal Saudi Air Force (RSAF) is one of the developing air forces in the region. A result of the revolution of innovation has constrained RSAF to update the F-15 fleets and purchased new models from the USA and UK. Lack of parts can influence both the availability of RSAF and the proficiency of maintenance activities. Likewise, the deficiencies may consume the assets of RSAF staff personnel .

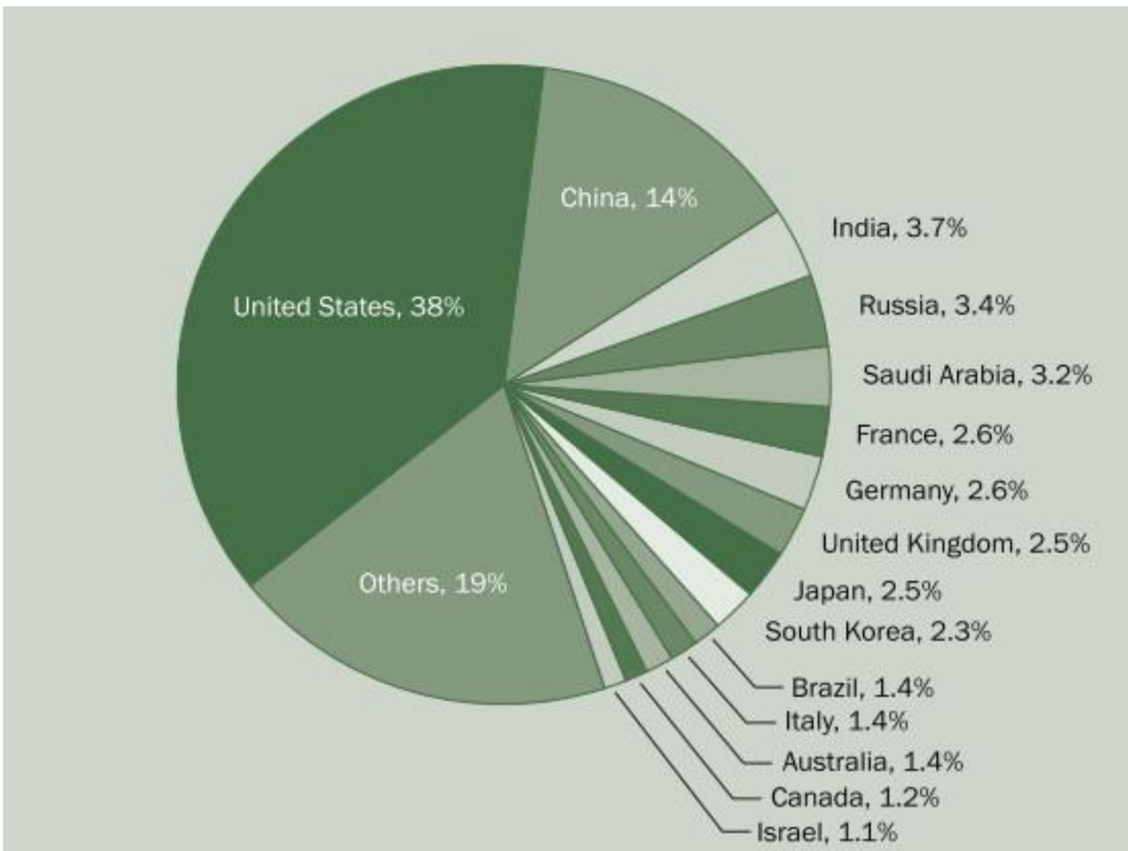


Figure 1. Military Expenditures in the World (Perlo-Freeman et al., 2016)

1.2 Problem Statement

The Royal Saudi Air Force (RSAF) is encountering a deficiency in the supply chain in specific parts because of malfunctioning parts. This issue is causing a supply chain disturbance in F-15 and Hawk aircraft where money and efforts are wasted in RSAF. A few factors are affecting this issue, such as climate in KSA, quality management system, and feedback. Those factors should be investigated.

1.3 Research Objectives and Questions

The primary goal of this research is to explore external factors such as the process and reliability of spare parts and environmental effects in RSAF. These factors can lead to mission failure where a shortage in part will occur and cause Non-Mission Capable Supply (NMCS). Identifying the problems will assist in solving this issue of waiting parts.

The research question is:

1. Which factors are the most contributing that leads to the parts deficiencies causing a shortage of parts for the RSAF fleets?

The investigative questions are:

1. What are the parts that usually experience a deficiency?
2. What are the human factors related to spare parts discrepancies?
3. Do failures occur in a specific season?
4. How is the reliability of parts calculated in the RSAFand are they different among fleets?
5. Which metrics are most appropriate to evaluate quality divergence that leads to parts shortage?

1.4 Methodology

In this research, the analysis will be mostly qualitative, with some quantitative, of shortage deficiencies due to part failure. Understanding the flaws between the end-user from both sides of the supplier and customer could better result in solving the problem. The data used in this research is a study of historical data available from the RSAF in the last five years, through available material management reports, quality reports forms, and papers. Besides, the researcher will use two surveys in two different departments within RSAF, and working companies such as Alslam and British Aerospace System to interview technicians and suppliers who experienced parts failure. Those surveys will be used to determine which factor has the most influence on part discrepancies. After collecting the data, an analysis of the information will be conducted.

1.5 Assumptions and Limitations

The following assumptions and limitations will be made to constrain the scope of this research project. The research will be focusing on the F-15 C, D, and Hawk. The study will include only the parts most repeated over time. Those data of F- 15 will include quarterly data of 2019 and the previous year, and for the Hawk, data will be last year. The researcher will not deal with financial matters. Some of the limitations the researcher faced in this research is not being able to approach some classified data and personal at the bases due to time constraints. Obtaining the relevant data took time due to COVID 19 travel restriction from going to KSA.

1.6 Summary

This chapter provided an overview of factors leading to the high demand for spare parts on RSAF fleets. Section II will review previous research in this area of causes part issues and analysis and suggestion methods in solving this issue. Chapter III explains the methodologies used in this research to identify the most probable cause, which affects spare parts reliability. Chapter IV gives an analysis and recommendations for the problems. Chapter V gives a synopsis of the data, the research conclusion, and suggestions for future effort.

II. Literature Review

2.1 Chapter Overview

This chapter presents an overview of different resources material studied while researching the problem statement of this thesis. A literature review will be conducted as a precursor to performing research in RSAF and other resources that could help in addressing the question of the problem mentioned. The report will discuss the repairable parts and quality improvement program in the RSAF. Additionally, there are books, journals that published and discussed these common issues for repairable parts criteria. The themes were relevant to the study of these topics.

2.2 Supply Chain Initiatives in RSAF

Shortage in parts could lead to a severe issue causing supply chain distribution and more time and money to resolve the issue. Many initiatives have been taken by RSAF members to mitigate this concern. A former researcher at the Air force institute of Technology (AFIT), Ali Alsheri, evaluated the source of repair performance in the supply chain map for repairable parts to identify the common mistake that RSAF might commit. In Alsheri's research, he noted an analysis conducted between the RSAF and United States Air Force (USAF) in 2011 to resolve issues in the supply chain at the enterprise level. To explain , he stated that "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 (Alshehri, 2015). He added "To date, supply chain improvement initiatives by Royal Saudi Air Force supply managers have been undertaken to eliminate any waste within the supply chain internal processes (Alshehri, 2015) (p12). On the other hand, few articles discussed the parts deficiencies at the enterprise level.

2.3 RSAF Supply Chain Map

To begin to understand the problem, an analysis of the causes of failures needed to be investigated in the supply chain. Those failures are causing more time to repair and consume valuable resources. Understanding supply chain mapping (SCM) could lead us to identify the area of weakness in the supply chain. Ali Alsheri mentioned in paragraph 2.2 that: “The F-15 reparable parts supply chain process currently requires too much time to repair and return parts that affect the capability of operational aircraft missions supply chain”. Also, in the same article, he stated that “Mapping of the supply chain is the first step to solve any problem and improve the environment of the supply chain.” (Lambert, 2014) (Alialsheri,2015) (p 20). He added, “Management of the relationships starts from the source of the raw materials to the end consumer of the final products or services to create better visibility of any activity inside that supply chain” (Alshehri, 2015). Last, supply chain mapping(SCM) is a powerful tool to help in management for those relationships to include all the parts of institutions that exist within the supply chain.

2.4 Software Tool

Some technologies provide organizations with software solutions for planning and execution to manage supply and aircraft maintenance operations. Those programs managed product flow, financial flow, and information flow for complex assets operating in air and ground environments such as system GOLDesp. GOLDesp is "deployable software specifically designed for aftermarket logistics support, maintenance, supply and repair operations, and PBL program management" (GOLDesp Product Overview, 2013). The system manual stated that “it can handle suite merges global asset visibility with complete product life-cycle management into a COTS application that can support a customer's total maintenance and supply needs across the enterprise" (GOLDesp Product Overview, 2013). Miro global company for technology (private company) provides solutions through technology that facilitates logistics enterprise within RSAF integration to help organizational agility, optimize supply chain management, and reduce sustainment costs. On the other hand, analyzing parts deficiencies as part of the software packages can cost much money. Also, parts need expert feedback for the improvement process of the elements. Figure (3) illustrates the organization involved in parts cycle reporting in the RSAF.

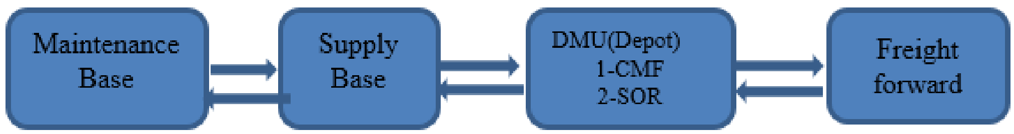


Figure 2. Flow Chart of the Reporting System

2.5 Failure Analysis Approaches

Any air force is dependent on spare parts availability they own, and how much they have in inventory is dependent on achieving a high level of readiness at all times. The performance improvement process considers one way to accomplish that. However, focusing on making the required Key Performance Indicator (KPI) for the organization could lead to extra expenses. Analyzing the most critical factors and scope for improvement can allow leaders to allocate resources more efficiently. This is discussed in Maintenance Metrics for United States Air Force (USAF)(Rainey, 2001). Another comment the author stated is, "Overemphasis of a particular metric while ignoring the root cause of a problem may well lead to an improvement in the metric but worsening of the problem" (Rainey, 2001).

The failure analysis team can address the other hypothesized causes and prevent failure to happen if we follow specific procedures. According to a study by Berk, this system failure can be analyzed by a Four-Step Problem-Solving Process (Berk, 2009) shown in figure (3).

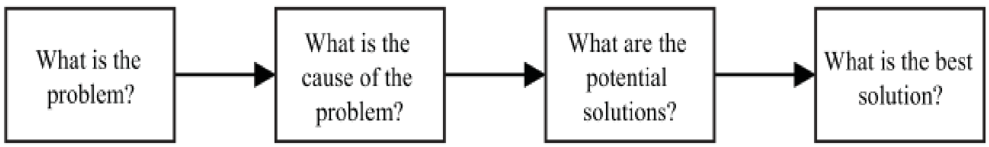


Figure 3. Failure Analysis Process (Berk, 2009)

For analyzing the factors needed to be studied, the researcher will require investigation to find the causes of the problem. There are different failure analysis and problem-solving methods used to understand parts and process failures. In 2018 Brown in his article stated that: "There are many different methods for performing Root Cause Analysis (RCA) that is defined by their approach or field of origin such as Five whys, Ishikawa/fishbone diagram, Failure modes, and effects, Barrier analysis" (Brown, 2018). These methods have different ways to find root causes with varying degrees of efficiency, accuracy, and quality.

2.6 Application of Root Cause Analysis:

One of the RCA applications made in 2008 to identify some issues regarding failure in the supply process is as follow:

In 2008, Lockheed Martin's facilities maintenance and operations team had a counter-flow, mechanical draft cooling tower designed and installed on *site. Upon installation, an unidentified gearbox experienced infant mortality caused by an existing production defect, and it has been replaced three times, so they initiated an investigation using root cause analysis tools. All the gearboxes have been placed on a vibration analysis route, allowing their behavior to be tracked. The failed coupling on gearbox No. 3 led to a condition assessment of the sub cell from that they identified the causes and initiated quality improvement process. These changes gave them a larger window to prepare for failures and are preventing unexpected downtime scenarios, which helped them to increase customer satisfaction (Troyer, 2019).*

Methods of root cause analysis can improve services also. A case study was conducted in 2017 in Saudi Arabia using Failure Mode Cause Analysis (FMCA) . The study was conducted on services provided by the Ministry of Hajj in Saudi Arabia to improve quality by applying the FMECA strategy to the Transportation System (Daif) in Holy Places during the Hajj and Umrah season. "They arrange the processes of the understudy system and then identifying the mistakes that can occur in each process and classifying failures according to their seriousness and propose how to solve it" (Mohamad& Jaziri, 2019).

2.7 Causes

Meantime Between Failure

In this study, reliability concerns of parts use terms such as mean time between failure. Analysts Victor and Terrell at Schneider Electric explained this term in their article. They stated that “MTBF is a reliability term used loosely throughout many industries and has become widely abused in some. It is time where Assumptions are required to simplify the process of estimating MTBF"(Torell & Avelar, 2004). Torell & Avela noted that It would be challenging to gather information required to obtain exact failure time. However, they have mentioned that "all assumptions made for the part must be realistic"(Torell & Avelar, 2004). In their article, they provide common assumptions used in estimating MTBF. They mentioned how MTBF is calculated, which is equal to Mean time to repair (MTTR) and time to fail (MTTF). Note that, MTTF is the expected time to recover a system from failure. Figure 4 illustrates how the meantime between failure can be calculated. This means the parts cycle is the time takes to diagnose the problem at the source of repair and the time to fail again on site.

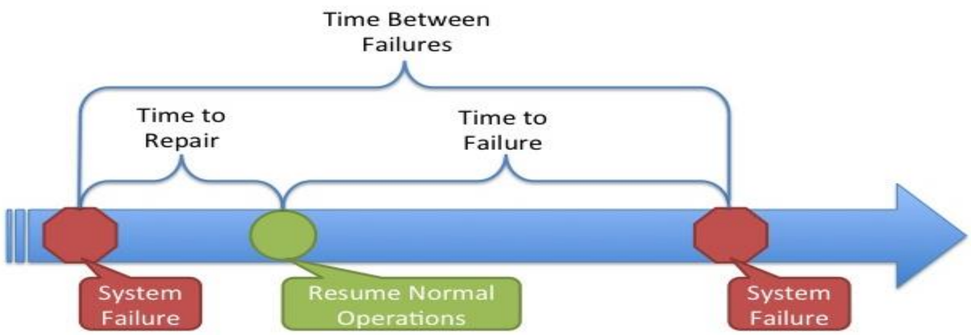


Figure 4. Mean time between failure calculation (Stephen, 2011)

Heat effect

In 1998 a study made by Pradeep, M. Pechet, Hakim to study heat effect where they mentioned the impact of temperature on microelectronics and system reliability (Pecht et al., 1998). They discussed different temperature-related models that were used to derive derating criteria for determining the maximum and minimum allowable temperature stresses for a given microelectronic package architecture (Pecht et al., 1998). The authors provided guidelines for the thermal rating of microelectronic devices, which can help to lower the junction temperature. They discussed how to use physics-of-failure models for various failure processes, to measure the factors such as the sensitivity of device life to variations in manufacturing defects, device architecture, temperature, and stresses(Pecht et al., 1998). The causes of overheating in microelectronics in any device might come from external resources causing it to fail. In this situation, engineers need to look at an environmental condition that provides a realistic assumption.

2.8 Summary

During the literature review, it was clear no past investigations on parts discrepancies used for improvement at the RSAF fleets. This gap required to explore the research questions mentioned in chapter I. Causes mentioned in 2.7 of chapter II will be examined in this study. Factors causing failure of parts and making maintenance work more in the RSAF fleet should be improved.

III. Methodology

3.1 Chapter Overview

On this chapter the researcher will describe the foundation of methods used in this research and discusses the development. In this section, the ressercher will describe details about data collection and the methodology used for analysis.Also, the researcher will discuss a method for utilizing the effect of the external cause on part failure causing shortage within the RSAF organization. This research will address some shortage reasons, frame it with comparession and questions, and utilize previous RSAF / worldwide studies to help to figure out causes.

3.2 Thesis Objectives

The research is focused on parts broken and quality program improvement at the base level and repair time at the enterprise level. The intent to set the stage for follow-on studies later on. Three principle methods provide a framework for this study. The first step is to identify objectives, metrics, and required data sets to reflect the research objectives and questions.

Objective:

1- Provide the external factors impacting part failure in the RSAF fleet.
   a) Weather impacts on the reliability of spare parts
   b) Compare some characteristic of spare parts in two different fleets
   c) Analysis of Source of repair for the F15 for abnormal behaviors for:
      i. Shipment flow time
      ii. Turn Around Time (TAT)

2- Provide a qualitative discussion on human factors.

3- Provide a qualitative discussion on discrepancies that occur in a specific season.

4- Provide a discussion on RSAF metrics for Not Mission Capable Supply (NMCS).

Metric:

1. Average mean of time for repair in the F-15 and contract obligatory agreement time.

Data:

1- Time of failure during the year.

2- Component reliability performance.

3- Provide statistics of the top critical part demanded by RSAF.

3.3 Structure of the SCM

Understanding the architecture of the supply chain in RSAF helps in what can discover an issue. The researcher needs to perform the beginning evaluation for the supply chain maps results done by a former researcher at AFIT, Ali Alshehri (2015). What are the deficiencies he found through the flow of parts and methods of transportation represented the average flow time for the elements in each stage on the supply chain map? Root causes methodology will be conducted on the overall system, including supply chain relationships between the base and other key nodes of the supply chain. This section presents the architecture, including components and interfaces, to aid the reader in an understanding of the part life cycle. The basic idea behind this to evaluate the system feedback for the design of the repairable part and compare the behavior information of the repeated parts.

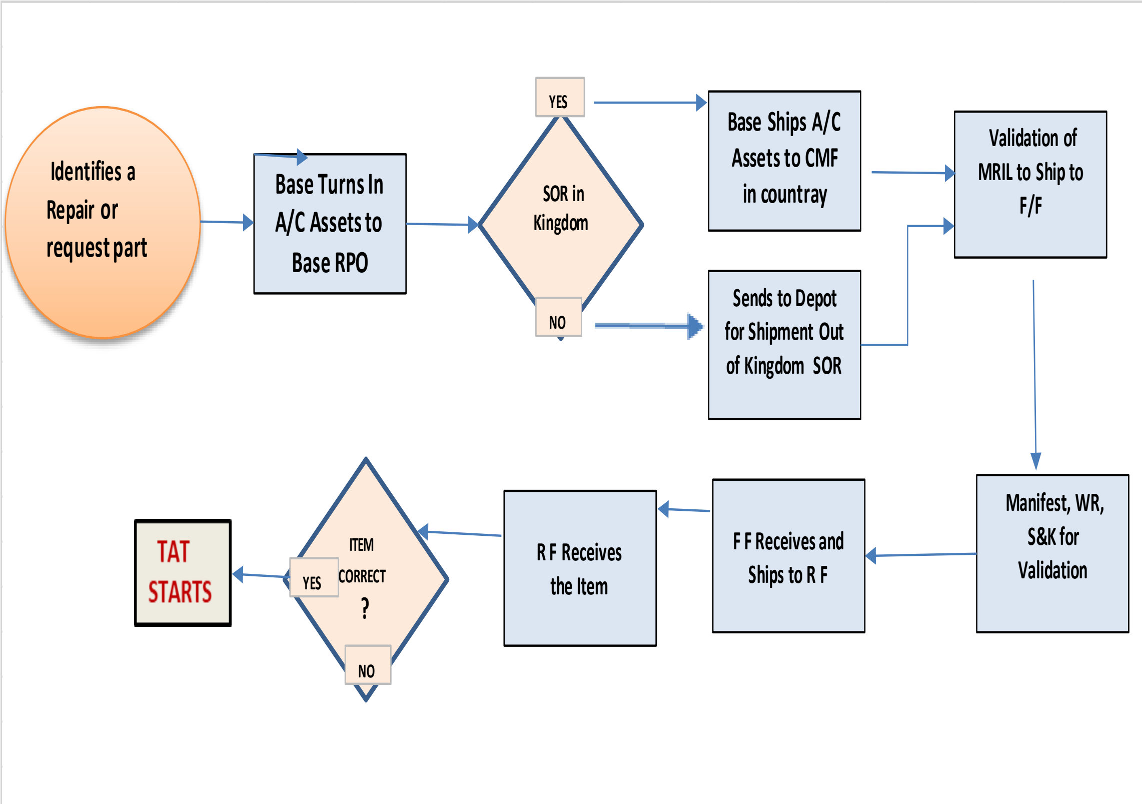


Figure 5. Flow Chart of Life Cycle of Parts

Figure 5 outlines the part stream diagram,.the guide to distinguish the procedure of the existence cycle for the spare parts. The process begins when the specialist gets code for a particular airplane after initiating a work order on the database tool for the supply chain (A GOLD system). After that,he then removes the broken parts of the plane and sends it to material control to be shipped to the supply squadron with all needed information Simultaneously, quality overseers are required to do check reviews on these parts to do an assessment on those parts and the data utilized. From that point forward, the supply unit checks the procedure for completion. Those procedures are equivalent to the two fleets. Depot supply receives the parts from the base and send them to be shipped to a freight foreword for the RSAF 15 and Hawk. Fig(6) illustrates the removal of the components flow within the airbase.

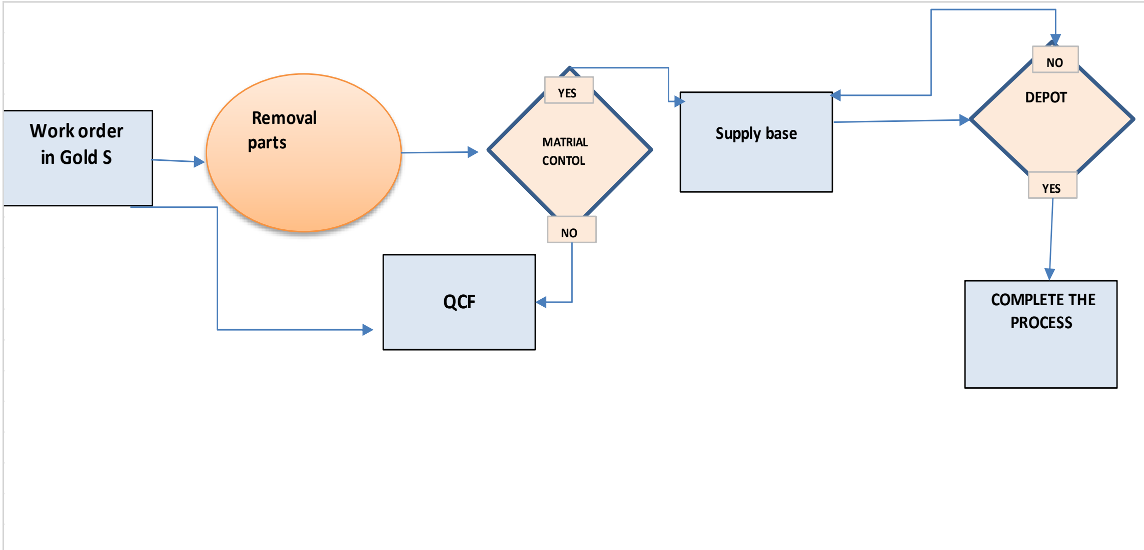


Figure 6: Parts removal process in the airbase

Since the process previously referenced in section two about the source of repair performance, the study will incorporate the kinds of spare parts getting repaired in the RSAF fleet and compare it with the Hawk fleet concerning climate effect. The study will take place in Tabuk airbase and the F-15 program depot.

3.4 Data Collection

The F15 Fleet

Data will be gathered from two sources: first for the F 15 supply squadron at Tabuk Airbase for the last year and from the previous researcher Naïf Alatwi at AFIT who worked on the F-15 program(Naif Alatwi,2016.). The data provided to him was a description process from a terminal in RSAF to the Warner Robins Air Force Base in the United States and the route back to the depot supply program in KSA. For RSAF, reparable parts organized in the Microsoft Excel sheet will be analyzed. The data of 2015-2016 selected consists of 2094 pieces. The data was sorted to the high demand to be distinguished to the most critical parts numbers at various SOR. Those data incorporate the information of report shipment of the material to freight forwarded (demand customer input), report of material from repair facility input, and report date of receipt in the country. To check the verification, feedback, and the time to start the process of these parts, more data was needed to investigate from other different assets in RSAF for this study.

The Hawk Fleet

Historical data for the critical parts were taken from maintenance squadron at Tabuk airbase and reliability performance for those parts from the quality department of the hawk fleet.

3.5 Survey

Two surveys will be developed to collect information about deficiencies regarding parts issues

Online Base Survey:

For F15 C, D parts from different departments, sampling participants' responses will be evaluated in chapter IV. The survey is intended to help increase a superior comprehension of the issue. The survey was utilized to examine whether a failure caused the disturbance in the supply chain, or are there different variables add to this issue, such as deficiencies in quality programs, supplier performance, and lead time for repair. These questions will be:

1. what is your current position?
2. What is your experience year on parts failure analysis?
3. From your experience, how would you rate the quality of electronics parts?
4. Are the electronic deficiencies seasonal?
5. How fulfilled are you with the reliability of parts repaired?

6. How long is the process of continuous improvement being implemented for defective parts?
7. How effective the quality management program in discovering parts issues in your organization?
8. How quickly do suppliers follow on parts requests and parts defected?
9. Do you think the purchasing process in your organization has improved?

Supply Manager Interview

It is vital to compare a particular aspect of failure in spare parts for another fleet to perceive what sort of insufficiencies that occurred. Mr. Alsayrai is from Tabuk airbase, a specialist on the quality management system and supply chain for the Hawk fleet that will give the required data to this research. These questions will be sent to him through his phone number request. The answers will be shown in Chapter IV.

The questions were:

1- What are the critical parts that usually experience failure, and when?
2- How long the process for parts take, and what are the criteria for it?
3- What are the conflicts that might make contracts differ from RSAF matrices regarding measuring quality performance?

3.6 Participants

The participants will be from Tabuk airbase, which contains both the F 15 and Hawk fleet. A portion of the individuals function presently on the F15 program, and they have experience on the Hawk fleet. Members already have a good background in spare parts. Grouping them with the current position will give the researcher an assortment of reactions to comprehend the issues. The survey will target the workers in RSAF (technicians, supervisors, quality inspectors, and suppliers). All the specialists have completed their Certification Professional Record (CTR) that is needed to work alone on the aircraft (level 7). Supervisors need to have a background in maintenance and education courses on team leadership and risks analysis. Quality inspectors have to have experience in processes, parts, and quality verification programs.

3.7 Tools

Analysis

The diagnostic analysis for the data will be conducted with the help of tools such as excel and JMP. Both are tools that can be utilized as a quality control evaluation by using historical data to monitor the efficiency of the process needed. The analysis using comparison also by those tools to find an answer for research questions.

Cause and Effect Diagram

Another tool is used to identify factors for parts deficiencies by implementing root cause analysis techniques.This technique called fishbone. Fishbone is known as Cause and Effect Diagram. Originally the fishbone technique was created by Dr. Kaoru Ishikawa, who is a Japanese quality control expert. Dr. Ishikawa initiated a tool for understanding the main drivers of an issue, which became later on commonly used. The analysis in the fishbone chart starts by breakdown the issue needed to study into causes and their effects. It names down causes and results in a way that they could be viewed for each activity and effect per activity.

3.8 Summary

In short, this chapter mentioned the development of objectives, metrics. It required data that will meet the study objectives and questions in Chapter I. In this research, highlight the factors and comparing it to the actual data collected will be the main purpose the researcher to work on it. The results of the investigation will be presented in Chapter IV.

IV. Analysis and Results

4.1 Chapter Overview

This chapter discusses the factors of the RSAF spare parts issues in Chapter III. Multiple information was collected from the information provided and studies. Surveys were administrated to a base level of F-15 and enterprise-level for the Hawk fleet to compare them with other analyses of historical data from the F-15 programs and Hawk. The report will be mostly qualitative with some quantitative observations to answer investigative questions in Chapter I.

4.2 Data Preparation

The data gathered from KFAB contain 456 consumed parts in the second from the last quarter of 2019 for the F-15C. Information on the most used reparable parts for the third quarter of 2019 and data of 2094 items repaired in the Source of Repair (SOR) from Jan 2015 to Dec 2015 with a different repair status.

In this investigation, the analyst centered around high consumed parts in each quarter of time parts. An analyst deleted some data, such as incomplete status. Turnaround time additionally was another factor. The data were from historical average repair time for specific spare parts repaired on the Material Report identification list (MRIL) of RSAF. Another analysis of the data made on the Hawk fleet contained 257 consumed spare parts for 2019.

4.2 Data Analysis

The data analysis consists of three sections. They are Data Finding, Survey Finding, and Supply Manager Interview. The results will be shown in different perspectives and analysis.

A. Data Results

For the intent of the research, the researcher focused on the most critical parts of both fleets. Two elements were considered: first, the time of discrepancy occurs, and the lead time for improvement. The initial phase in assessing the spare part circle is developing the supply chain map for part removal referenced in chapter II (Fig:5). The second step is to construct a root cause diagram using the fishbone technique. The root cause diagram recognizes underlying issues on the part life cycle see (Fig:7). Some discrepancies needed to be explored more in later studies. Factors such as climate impact lead time, lack of quality of parts, and QMS will be of concern. The relationship between the time of parts removed and timely completion for the repair process will be investigated.

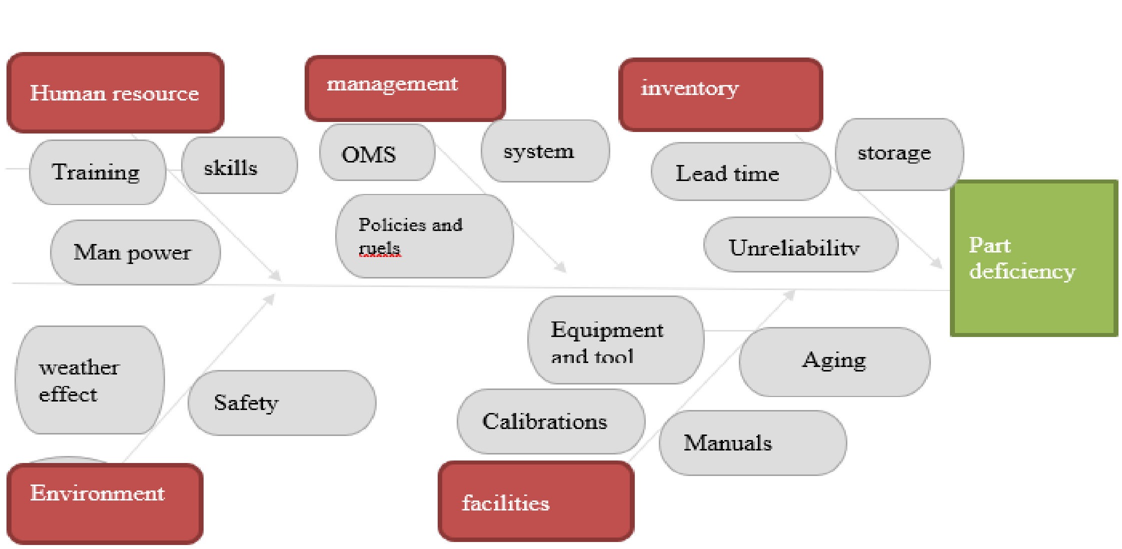


Figure 7. Root cause analysis for part deficiencies

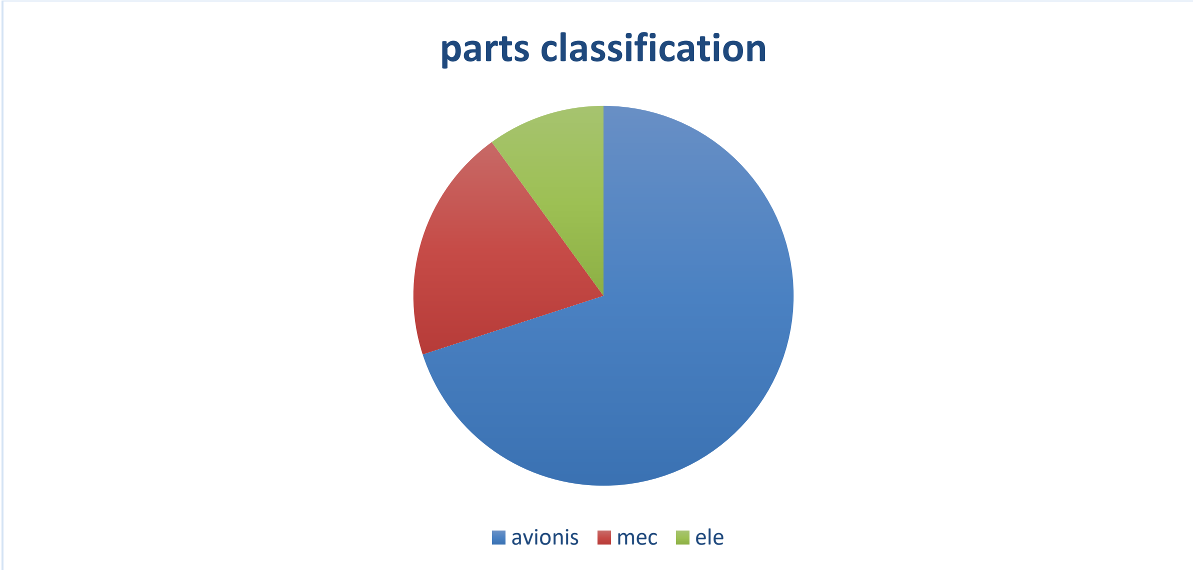


Figure 8: Part category discrepancy of F-15 C

Analyzing the data shows that there are more inconsistencies in the second from the last quarter of the avionics parts, with 70% of the spare parts failing during this season. Mechanical may be effected in another season. Fig (8) illustrates the top critical elements on the F15C from Jun 2019 to Sep 2019.

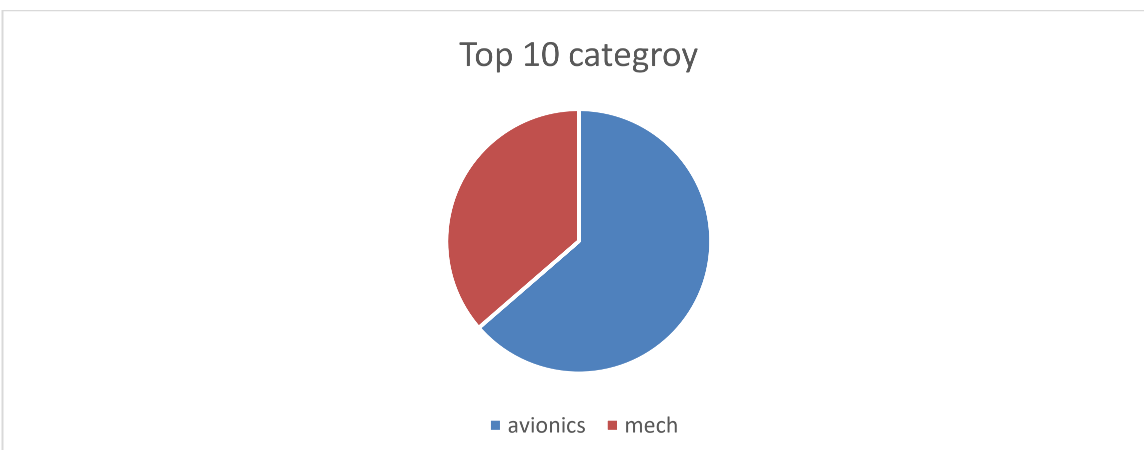


Figure 9: Classification of Part Discrepancies in Hawk

Similarly, analyzing given data for Hawk fleets shows that there are more inconsistencies in the third quarter of the for the avionics parts,65% of the parts break during this season than mechanical parts. Fig (9) illustrates the top critical elements in the Hawk fleet.

Relationship between avionics failure and seasonal effect time

The demand for spare parts differs from season to season. To demonstrate the demand rate, a sample size of 60 observations for a specific part was used. The aim of the analysis is to gauge the impact of temperature change on part discrepancies and assess how many numbers accrued per quarter. Figure (10) delineates the circuit card part throughout the year. Note that information had a deferral of one month to two months for the RSAF procedure to be delivered to freight forward, as referenced in chapter II as shown in figure (11).

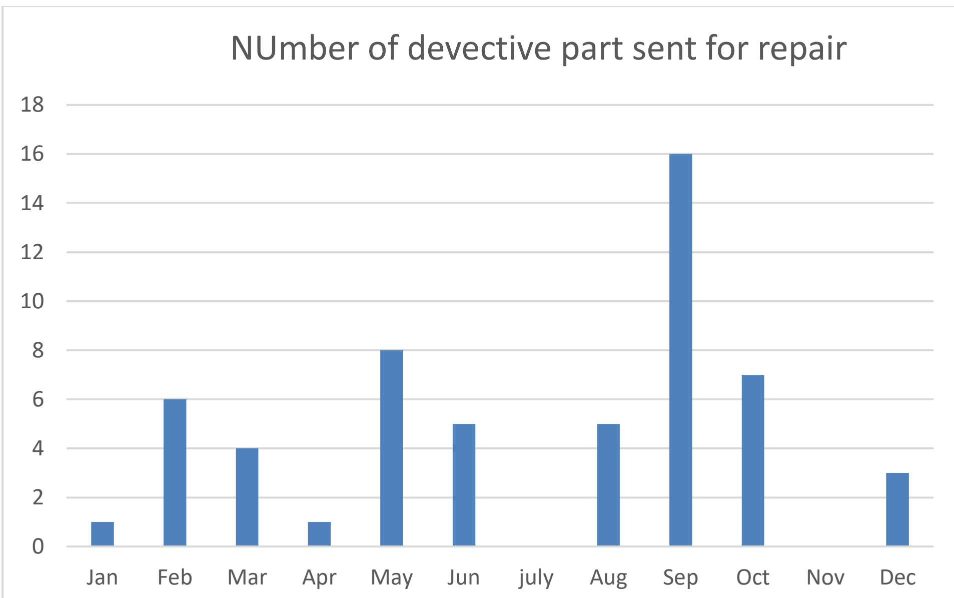


Figure 10 input customer by Freight Forward

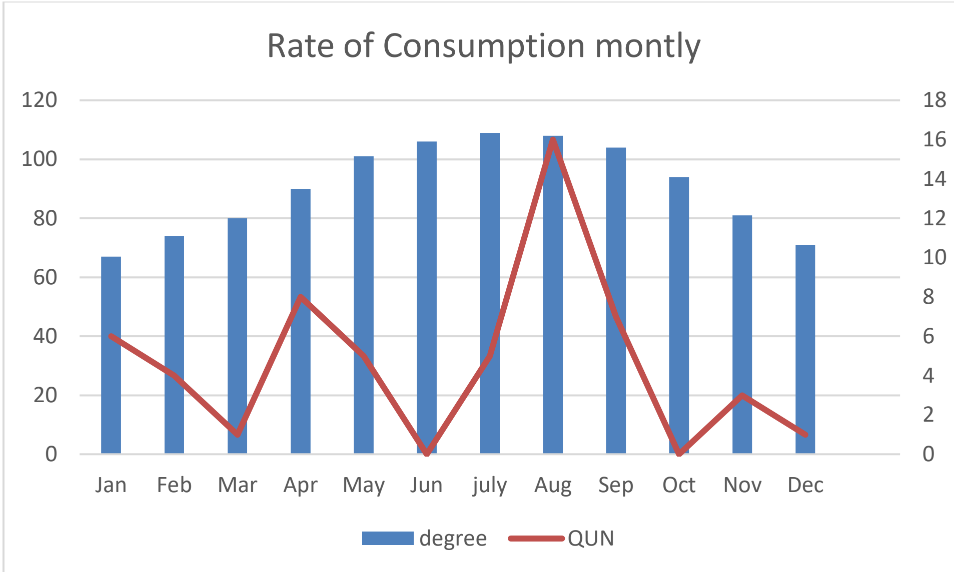


Figure 11: Actual Monthly Broken Parts (CC)

Reliability of parts (MTBF):

In this study, the researcher took a number of spare parts that are critical and compared them to two fleets and manufacturing designs for some parts of the hawk fleet. A comparison can indicate the parts' performance.

Summary data

The summary statistics will be from data of high demand parts for 2019. The five selected five spare parts of Hawk aircraft in the table (1) and compared with other fleet and manufacture design. Table (1) provides a comparison with the manufacturing design, another fleet in different locations, and hawk fleet in Tabuk .

Table 1. Summary Statistics of MTBF Comparision in hours.

Statistic	MTBF		
	Fa design	Another fleet	Saudi F
transponder	9100 h	9000 h	1500 h
Accelerometer.	3500 h	3300 h	1660 h
Mission,D.L.R	2800 h	2800 h	952 h
Unit D.L	2200 h	1100 h	700 h
Regulator	1500 h	1500 h	500 h

Another methodology the analyst used to quantify MTBF viability of the F-15 was breaking down a sample for a part known as Dual tape (DT) for 32 items in 2015. Analyzing the sample shows that the meantime to repair (MTTR) of a (DT) with a matric of average turnaround time for these parts as follow :

1- Eleven pieces exceeded the time to repair according to manufacture matric.
2- Four parts took less the average turnaround time.
3- Thirteen pieces were condemned.

Lead time for the spare part

Lead time is a factor to consider. Alsheri referenced in chapter II about the performance of SOR facilities. He stated that

> "*Delays are also being incurred due to documentation errors, missing components or parts, and putting broken parts on the shelf instead of shipping them for repair. The following are findings and recommendations resulting from this study" (Ali,alsheri,2014*).

Another finding found by the researcher is that the procedure is taking a great deal of time before shipping to the repair facility to begin the repair process (turnaround time). Since the sources of repair are can not start the process of repair until all documents and components are complete, the research found that there is a number of days added to contract time by an average of 70 days according to the metric performance in the contract. It is determined from the reported shipment of freight forward or repair facility (customer input) to report material in the country on a mean average of 150 days. Figure (12) illustrate the number of days that parts remain in repair parts facility.

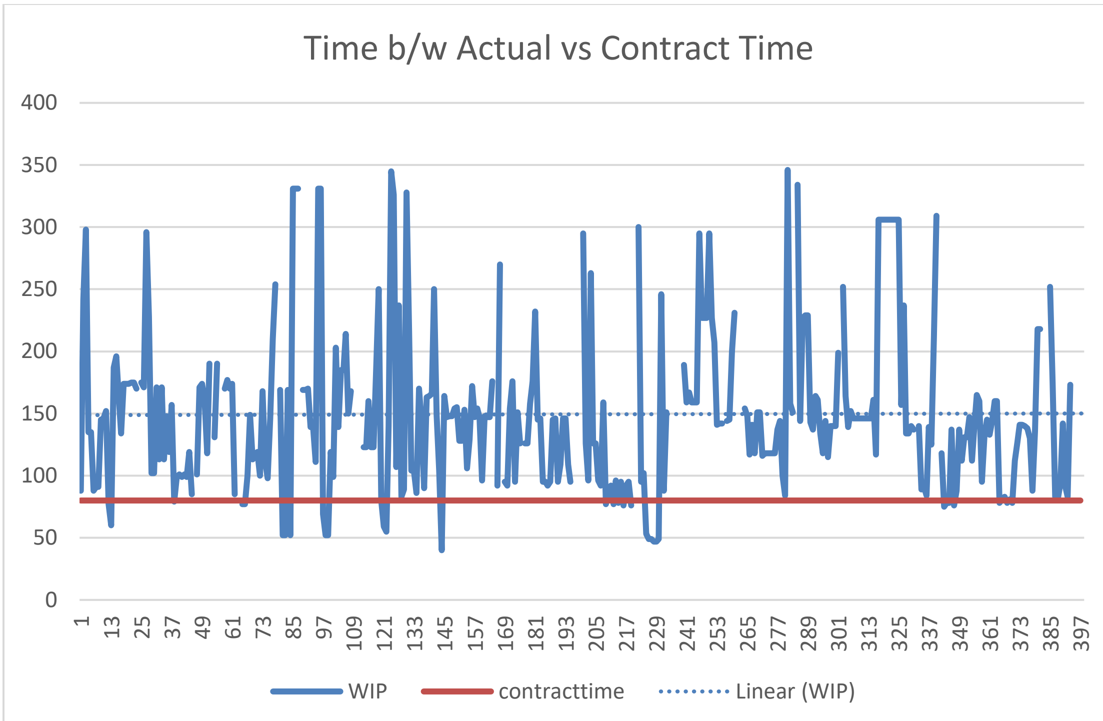


Figure 12:Gap in Days before Repairing Parts

Quality Varication Reports

A sample of quality varivication reports (QVI) was gathered during 2019 for the F-15C. The purpose was to check the cause coded for parts discrepancies. The researcher found some codes are not appropriate to the spare parts malfunction. Few reports were written against technician maintenance assessment, certified maintenance supervisor (CTMA) due to technician error. One report for a material item using quality deficiency

Assessment (QDA) is shown in Table (2). The cause of fewer reports made the researcher acquire worker opinions on quality program effectiveness in the F-15 fleet. Table(2) illustrates the number of quality reports written in the last year for maintenance squadron.

Table 2: Quality Reports for 2019

Database	***JAN***	***FEB***	***MAR***	***APR***	***MAY***	***JUN***	***JUL***	***AGU***	***SEP***	***Total***
QDR	**-**	**-**	**-**	**1**	**-**	**--**	**-**	**-**	**--**	**1**
CTMA	**2**	**-**	**2**	**-**	**1**	**-**	**1**	**1**	**1**	**6**
CSMA	**-**	**-**	**1**	**-**	**-**	**1**	**-**	**-**		**2**

B. Survey Findings

The survey took place with the F 15 program worker. Twenty-four individuals addressed the survey questions were from the workers on the improvement program for the F-15C. Technician, supervisor, and quality inspectors of Tabuk airbase (referenced in section three) who addressed the study were asked if there is a connection between period of failure for avionics parts and parts issues. The opinions of F/15 respondents on how they feel toward their experience with part deficiencies. Several findings required improvements from the supply chain manager at RSAF. Those discoveries make the process of spare parts easy to fix and productive with shorter lead time. Additionally, parts discrepancies can be characterized as waste and eliminated through a continuous improvement program. The types of issues observed in the supply chain are lead time, applications of the quality management system, feedback, suppliers cooperation, and absence of needed equipment.

After collecting the raw responses to the online surveys, the information will be described and summarized in bullet lists and charts to make it easier to understand. These findings added to the life cycle for the parts. Consequently, it will have a limitation in the supply chain. In the following are the outcomes:

Seasonal Effect Response.

The vast majority of the participant agreed, as shown in figure 13, that discrepancies occurred in the second and third quarters, especially in the summertime, responding yes by 75%, where 12.5% disagree, and 12.5% have no idea about it.

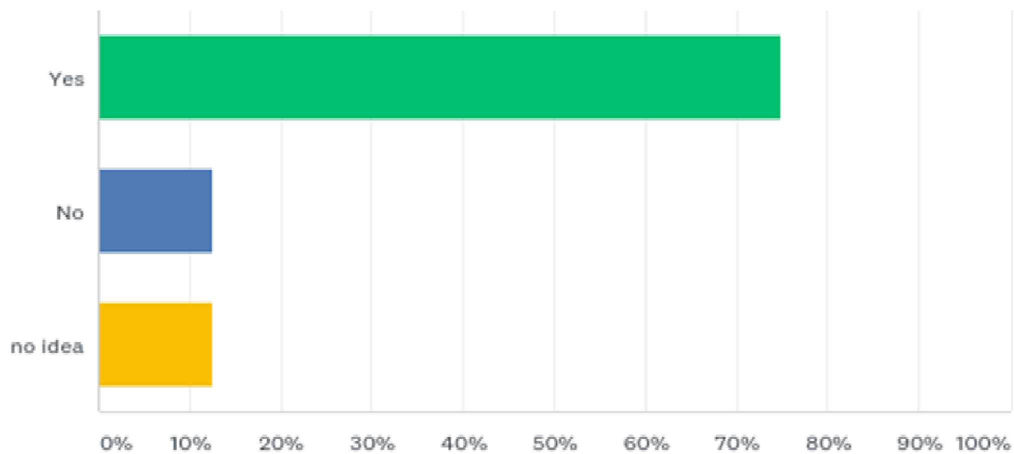


Figure 13. Percentage Agreement on Season Behavior on Parts by Participants

Reliability of Spare Parts Repaired

When the researcher asked about the reliability of the spare parts that were repaired, 37.5% were satisfied with the piece fixed, 20.83% were dissatisfied, and 41.67% had no judgment on repairable parts. Figure 14 illustrates the participant's response toward the quality of repairable parts.

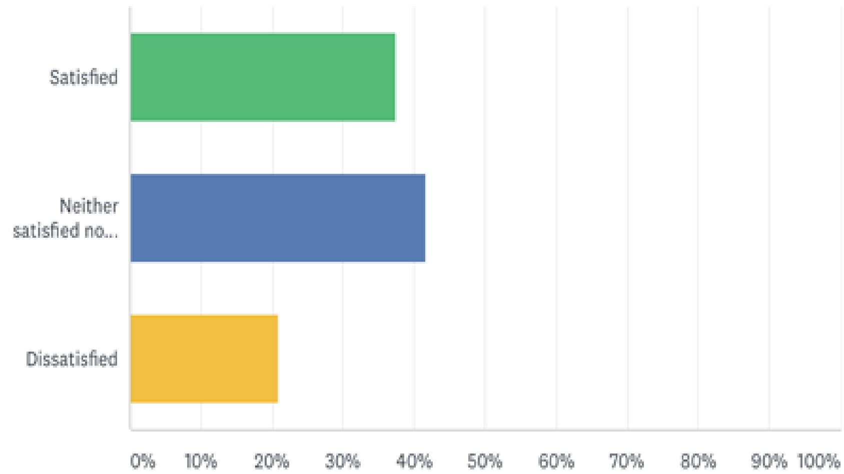


Figure 14. Reliability of Repairable Parts for 15

Quality management system and feedback description

When members were asked about the process of improvement on defective parts, nearly 45.8% think that procedure is taking a reasonable time where half believe that it is too long. On the other hand, 4.1% think this process is taking a short time. The supply chain flow of information might have challenges that are slowing the parts repair due to the slow exchange of data. Since there is a link for communication between RSAF individual and other supply chain personal, data were taking a long time to get back. Delivery of these parts may take a short time. However, delays happen on data exchange data where this thing required improvement Figure (15) illustrates participant's responses toward the quality improvement process in F-15 C squadrons.

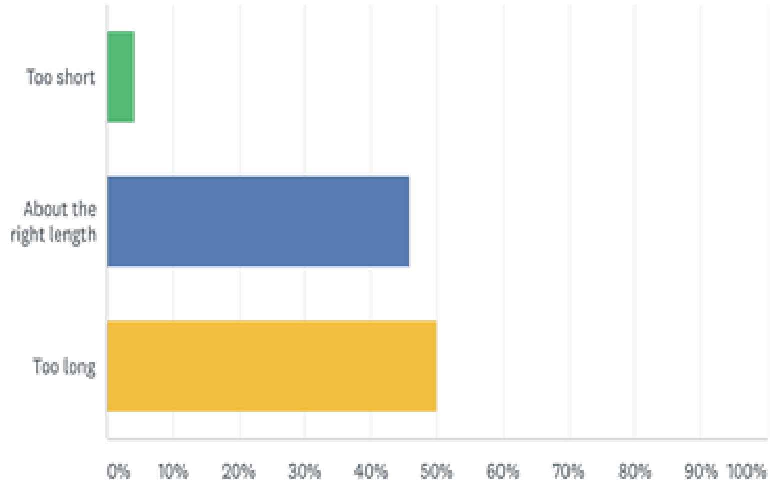


Figure 15. QIP Process for F 15 C

Respondents were also asked about how they view the effectiveness of the quality improvement program in their organization. 33.3% were satisfied with QMS inside the F/15 program, 20.8% were dissatisfied, and 46.2% were neither satisfied nor dissatisfied. Figure 16 illustrates the respondents' opinions on the quality management system performance within the base.

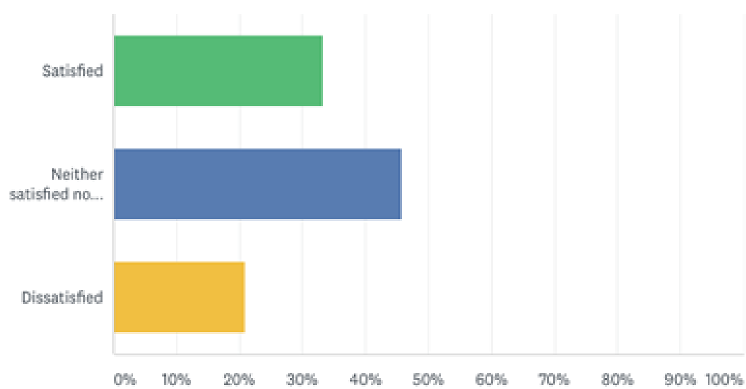


Figure 16. Percentage of QMS Performance

Supplier performance

The participants were asked whether the suppliers provide quick feedback on the defective parts. Their opinions were that it never took a short time, but the supplier response for the feedback was from medium to a long time to respond. Figure (17) illustrates the participants' responses toward supplier performance.

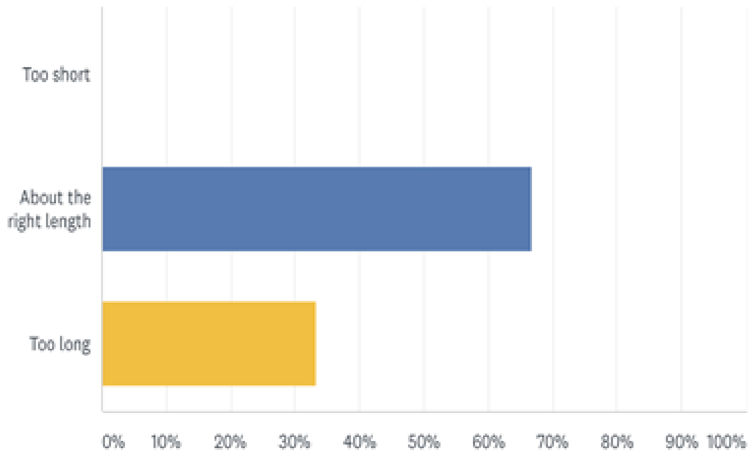


Figure 17. Supplier Performance

Another question was whether there is some improvement in the supply purchasing process in the F15. Their responses were 16.6 % agree, 33.3 % disagree, and the rest with neutral. Figure (18) illustrates satisfaction regarding the purchasing process in the new parts.

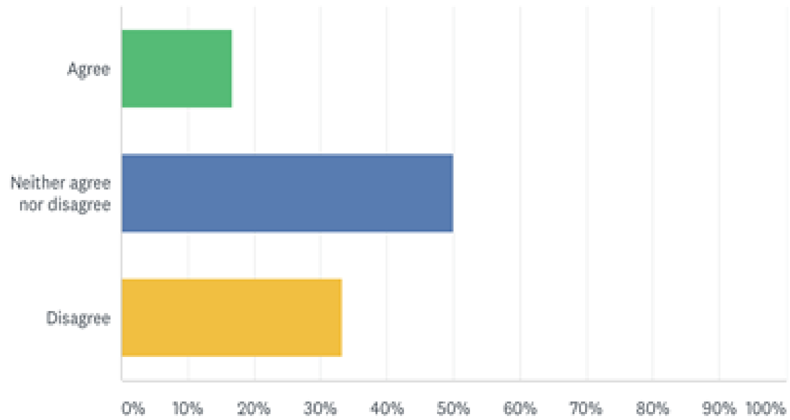


Figure 18. Purchasing Process

Survey Results

The result shows that there is a significant agreement by the participants of the climate impact on avionics parts. Similarly, the participants disbelieve the feedback is taking a short time to get to them. Qualified individuals from quality and supervision believe the parts repaired are reliable. On the other hand, five thinks that they are not acceptable. Regarding quality performance, there is a quasi-agreement with eleven people that they lack the data needed for improvement, where eight people believe the quality program is active. Five disagree with this effectiveness of the quality program. Lastly, on the supplier performance, no one believes that follow up on new requests, and defective parts are taking a short timeframe where the majority think it is taking a reasonable time to a long time.

Other findings

Participants were given the option to write their comments about any factors that contribute to the problems, four people responding to that. One of the observations was that there is a need for courses by analytics to train them on the Gold system.

C. Supply Manager Interview

To gain insight into Hawk fleet discrepancies regarding parts issues, the researcher interviewed supply supervisor over the phone, as mentioned in chapter III. Alsauray explains the challenges they face some time regarding spare parts availability, which has a negative impact on fleet readiness. He answers how the supply chain works and how they track parts in the level base and some hints for improvement. Also, he explained how the quality management system work and what are the challenges they have regarding standers in RSAF.

According to Alsayari, performance management for quality been monitor according to the RSAF rules and regulations. Performance factors such as extended time feedback response and MTBF are concerns for the quality department for making decisions. Also, the lack of skills for some workers makes challenges for supervisors because the current system cannot track individual performances after finishing his training.

Recovery plans were made to recover some parts discrepancies within the Hawk fleet. For example, impose new buy for the defective parts at no cost on the RSAF and acquire permanent engineering solutions from suppliers for those parts. Also, Mr. Alsayary mentioned that electronic feedback records evaluated on each quarter to substitute it with the current record feedback. Also, the quality department has been evaluated from the third party for improvement. Some quality inspectors in his fleet mentioned to Alsyaryi that the matrics within RSAF manuals can give wrong indication about the performance of the fleet based on the contract requirement .This concerns needed to be studied later oon in the RSAF.

Technology and process improvement create a new environment for development where the information can be obtained the data quicker and more efficiently to reduce cost and waste in the fleet.

4.4 Summary

In this chapter, Root cause that can affect components was examined by several measures, lead time, seasonal effect, and reliability of the parts. Narrative analysis techniques were used in the survey and interview . This chapter is dedicated to presenting mostly qualitative with some quantitative notes. Chapter V will provide concluding remarks, answers to the investigative questions from Chapter I, and recommendations for future research.

V. Conclusions and Recommendations

5.1 Chapter Overview

In this chapter, the results are summarized. This study was tested on an analysis of RSAF data. Investigative questions from chapter I are answered along with recommendations for future work.

5.2 Conclusion of Research

The main objective of this research was to explore the factors prompting expanding parts disparities in RSAF. The actual effect of external factors discussed such Weather impact, reliability of parts, lead time of repair, and quality system are investigated. Chapter I described the problem and the objectives for the research. The second chapter provided previous studies on parts inconsistent worldwide and techniques used in analyzing the data. Chapter III outlined the methodology for the research. Chapter IV provides a finding of the analysis of the study from two different fleets for comparison. The results highlight deficiencies in the turnaround time and flow data in the RSAF supply chain.

This analysis used data from two sources; the first was measurable historical data for the F 15 and Hawk. The F/ 15 C contained two parts: first, 456 consumed components last year, and 2094 sample sent for repair, where for the Hawk 257 samples of the previous year. Elements were organized in both Microsoft and JMP to provide better analysis. The second source was based on the evaluation of the surveys and interview findings. The output was displayed in charts and tables Those outputs show that those variables play a role in parts inconsistencies

5.3 Dusscion and Recommendations

The goal of the data analysis referenced in chapter IV was to achieve a clear understanding of the connection among variables mentioned in the objectives. Also, recommend improvement in supply chain activities.

The output shows that there is evidence of climate effect, reliability impact, feedback delay, documentation error, and lack of skill in software programs**.** The weather may hurt the performance of the electronic parts. The criteria for electronic parts include temperature, electric oscillation, base altitude, dust, sunshine, humidity, and of course, the components may not be designed according to the country circumstances. All those reasons will affect quality. Discrepancies rise during summer and fall time due to weather and which may exceed demand more than usual in the other times. This can be improved through a well-designed part to overcome this problem with venders.

One finding contributed to avionics parts discrepancies is that those parts cannot be repaired in RSAF. A late response to the quality management system or for the user to get feedback from the source of repair harms part development. That could result in a lack of interest form both the specialized technician as well as quality personals. In contrast, some parts need to be developed by the manufacturer

Lack of accurate feedback can result in a waste of time for both parties. This lack included waiting in process coded in time repair. After investigating the reasons behind causes, the results show that incomplete feedbacks occurred. Some of the parts need more information to start a restoration. Specialists who are required to file documents in Goldsep system may have difficulties in clarifying some complicated parts. Likewise, there are a few specialists not aware of some codes discrepancy. Entering incorrect information from specialists and suppliers is evident by comparing the actual time to the estimated time in most cases. The verification process through specialized departments can be implemented between RSAF entities and other sources of repair. This department will help to eliminate some factors that originated from the beginning of the parts process and source of repair and vice versa. Fig (19) illustrates the recommended improvement in the supply chain map. There will improve the flow of accurate information for both sides within the base level and source of repair. Fig(19) introducing the Quality Management Department in the supply chain would be a solution to monitor the flow data and varication

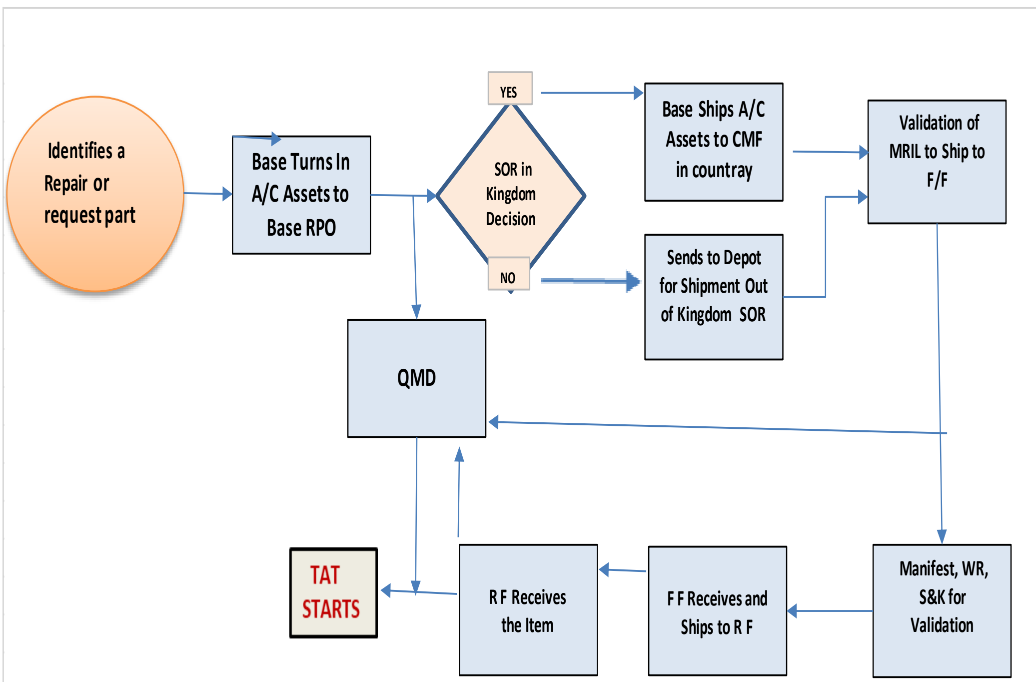


Figure 19: Introducing QMD in RSAF SC

Documentations consume time in the F 15, and workers face some challenges such as spending time in writing, inappropriate feedback, and incomplete information. All those issues can mislead analytics. Digitizing forms with specials codes and format would be one way for improvement.

Supplier performance required more attention regarding providing information of necessary parts, and all the needed materials, to compare with available data. The survey shows a weak relationship between the technician and the supplier. Lack of tracking technical matrices for part evaluation should be considered from a quality perspective. Establishing metrics in contracts will benefit both parties to measure the performance of parts.

5.4 Significance of the Research

The KSA, one of the top imported markets in the world for aircraft parts, form US and UK markets. An initiative started end-to-end in the supply chain can improve the process and reduce cost and time. One goal of the RSAF is to determine deficiencies throughout the supply chain for improvement. This thesis explored factors not mentioned before in detail, which is the next vital step in improving supply chain performance. RSAF is seeking continuous developments with suppliers to achieve the goals of both parties, including providing necessary parts of combat readiness and reduce the long lead time of repair and return processes.

This research discussed factors such as environmental impact, lead time for the repair, feedback system of the long customer-waiting time. Enhance the relationships between individual of the supply chain as well as using new communication presented in paragraph 5.3 will help improving supply chain activity . Also ,sharing analysis between RSAF personal and supplier will contribute to reducing the overall cost.

5.5 Investigative Questions Answered

1- What are the parts that usually experience a deficiency?

According to statistical analysis of the consumption rate ,avionics components are having more discrepancies than others but are easy to replace. It is considered most simplistic on airplane design to replace. The complexities vary between these parts based on the models and age of the aircraft. So executing a successful design for those parts required steps for improvement where environmental change should be assessed regularly. Additionally, management can help in decreasing a shortage that may occur by forecasting critical components according to the season and provide supply and maintenance facilities with the necessary equipment required for testing those parts.

2- Do failures occur in a specific season?

Yes, they are heat play a role in avionics part discrepancies. The heat affecting the electric component originated from two sources, the first one is the mechanical movement of the parts, which turns into heat, the second source is the heat surrounding the device, which added more heat to the piece, causing it to fail. This issue can be reduced by studying the environment in KSA and provide information to the engineer to make their design. All that helps build a design that can meet criteria for avionics parts include temperature, locations altitude, humidity ,dust, electric oscillation, etc.

3- What are the human factors related to spare parts discrepancies?

Despite the vital job of workers on maintaining aircraft, workers become part of the problem. This can be noted where the technicians have a lack of skill and decide to make a wrong decision on parts. The rate of parts consumed and sent to repair lead to the high cost to training issues or writing on wrong codes of repair in the form discrepancies also part damage during installation and transportation. The failure of quality personal to identify those issues will have a negative impact on improving parts discrepancies**.**

4- ***How is the reliability of parts calculated in the RSAFand are they different among fleet?***

It is calculated through (MTBF). For further detail, The correct assumption of the design plays a significant role in part reliability. Metrics should be evaluated regularly, such as MTTR, MTBF, and MTTF for any air force. To calculate the (MTBF) high-level statistics required meaningful data such as operational time, break time and work order by the technician, Those factors could run through software such as the Goldsep system for the second part of the question the answer is yes. The result were shown in table (1).

5- Which metrics are useful to evaluate quality divergence that leads to parts shortage?

As a quality management system that is used in RSAF to monitor the performance of the fleet, the QMS defined framework for the organization to work from how to document a process, procedures, responsibilities to meet the RSAF requirement. Measurement of the effectiveness of the quality management system in the airbase through NMCS matric is not the right tool to measure parts reliability to seek improvement. According to the ISO 9001 reject ratio, or first pass yield, is the appropriate KPI to be used to improve the products. MTBF will help to measure and monitor parts discrepancies. This method will control and enhance QMS and provide better management.

5.6 Recommendations for Future Research

This research can help many researchers that have been working on solving and finding solutions to the logistics problem in RSAF or in any other ally air force. In this section, recommendations for future research will be presented for more investigation. Following those recommendations will raise the readiness of air force by improving the process and the system. Suggestions for future research are:

1- Studying the process of digitizing feedback responses through special codes and fault isolations for the technician.

2- Introducing more fleet to study this phenomenon in different places.

3- Study the methods of reducing lead time by establishing SOR in KSA.

4- Explore the changes between the Quality management system being used in military manuals and ISO stander 9001 2015.

Appendix A.

On line survey for F15 personal

1.what is your current position?

2.what is your experience year on parts failure analysis?

3. From your experience, how would you rate the quality of electronics parts?

4. Are the electronic deficiencies seasonal?

5. How fulfilled are you with the reliability of parts repaired?

6. How long the process of continuous improvement to implemented on for parts defective?

7. How effective the quality management program in discovering parts issues in your organization?

8. How quickly does supplier follow on parts requests and parts defected?

9. Do you think the purchasing process in your organization has improved?

Answers for survey

Response (1)

ANSWER CHOICES	RESPONSES	
supervisor	37.50%	9
technician	41.67%	10
supplier	4.17%	1
quality management member	16.67%	4
TOTAL		24

Response (2)

ANSWER CHOICES	RESPONSES	
Under 10	33.33%	8
10-20	45.83%	11
above 20	20.83%	5
TOTAL		24

Response (3)

ANSWER CHOICES	RESPONSES	
High quality	16.67%	4
Neither high nor low quality	79.17%	19
Very low quality	4.17%	1
TOTAL		24

Response (4)

ANSWER CHOICES	RESPONSES	
Yes	75.00%	18
No	12.50%	3
no idea	12.50%	3
TOTAL		24

Response (5)

ANSWER CHOICES	RESPONSES	
Satisfied	37.50%	9
Neither satisfied nor dissatisfied	41.67%	10
Dissatisfied	20.83%	5
TOTAL		24

Response (6)

ANSWER CHOICES	RESPONSES	
Too short	4.17%	1
About the right length	45.83%	11
Too long	50.00%	12
TOTAL		24

Responce (7)

ANSWER CHOICES	RESPONSES	
Satisfied	33.33%	8
Neither satisfied nor dissatisfied	45.83%	11
Dissatisfied	20.83%	5
TOTAL		24

Response (8)

ANSWER CHOICES	RESPONSES	
Too short	0.00%	0
About the right length	66.67%	16
Too long	33.33%	8
TOTAL		24

Response (9)

ANSWER CHOICES	RESPONSES	
Agree	16.67%	4
Neither agree nor disagree	50.00%	12
Disagree	33.33%	8
TOTAL		24

Appendix B

Hawk fleet interview

The questions were:

1-What are the critical parts that usually experience failure, and when?

List of top critical parts

It deponed on the parts failing, for example, OX regltor nowadays.

2-How long the process for parts take for repair, and what are the criteria for it?

Long time for responses.

MTBF

The recovery plan

3-Does the MTBF consider forecasting criteria regarding parts failure in the fleet?

RSAF matrics for capable mission supply

New buy at no cost

Permanent engineering solution

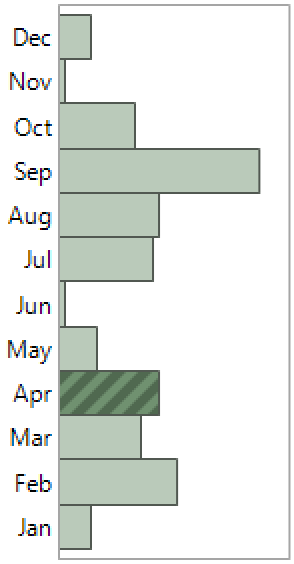
Different system and mitigation plan

Supplier performance evaluations

4-For what are the conflicts that might that contract differ from RSAF matrices regarding measuring Quality performance*?*

A company following ISO9001, and at the same time, it is obligatory to follow the RSAF manual. They do auditing from a third party.

Appendix C



Frequencies

Level	Count	Prob
Jan	5	0.03546
Feb	19	0.13475
Mar	13	0.09220
Apr	16	0.11348
May	6	0.04255
Jun	1	0.00709
Jul	15	0.10638
Aug	16	0.11348
Sep	32	0.22695
Oct	12	0.08511
Nov	1	0.00709
Dec	5	0.03546
Total	141	1.00000

N Missing 3105
12 Levels

Frequencies

Level	Count	Prob
1	10	0.14493
2	26	0.37681
3	22	0.31884
4	11	0.15942
Total	69	1.00000

N Missing 3177
4 Levels

Table of parts discrepancies in F15

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14. ABSTRACT

The Royal Saudi Air Force (RSAF) is experiencing a shortage in certain avionics parts due to a lack of reliability. This issue is causing a supply chain disturbance in the F1-15 fleet and the Hawk fleet. One of the factors behind this problem is the environmental effects in Saudi Arabia .The study will investigate and analyze the methods for the Improvement CycleProcesses and the Quality Management within the RSAF repair cycle. Finding show that, the discrepancies are risingduring summer and fall time due to the environment change, Other finding were addressed in the study

15. SUBJECT TERMS

Enviormental effect,MTBF,QMS

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